Diffusion of smart grid-innovations in a supplier-centric model

The role of the DSO as a change agent

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Abstract

The *smart grid* concept contains technologies and innovations that can improve the sustainability, flexibility and efficiency of the energy system. However, the diffusion of these innovations is slow. Despite a vast literature on the subject, the distribution system operators (DSOs) role within the innovation system has gained little attention. The DSO has a strong position towards consumers in the retail electricity market, being responsible for the operation and management of the electricity grid and the grid tariffs at the distribution level. Their role could, therefore, be understood as a *change agent* in the diffusion of innovation (DOI) theory.

The purpose of this qualitative research is to understand the role of the DSO as a change agent for the diffusion of smart grid-innovations. The future role of the DSO as a change agent in the Norwegian retail electricity system is especially important to study as the Norwegian Water Resource and Energy Directorate (NVE) is currently planning to implement a supplier-centric market model in the retail electricity market. By combining two theoretical perspectives, the systems of innovation (SI) perspective and the DOI theory, this study provides both a systemic macro-perspective and a relational micro-perspective to understand the DSO as a change agent, and the implications of the supplier-centric model. Four smart grid-innovations are investigated empirically in the research: prosumers, demand tariffs, battery storage and energy management systems. The position of the DSO is investigated by combining document analysis and six expert interviews.

The findings suggest that the DSO maintains a relevant position as a change agent following the supplier-centric market model. However, their standing weakens due to a reduced communication link to the end users. A reduced communication link has implications for their role as change agents, and especially at the knowledge-stage of the end user's innovation-decision process. The stage is considered the most crucial stage of the innovation-decision process, and a weakened link reduces the performance of the innovation system and the ability for smart grid-innovations to disperse within the market. Further, to improve their position at the knowledge-stage, the research shows that the DSO needs to strengthen the communication link towards the end users. In addition, to improve the overall situation in the innovation system, greater cooperation between the actors is seen as a solution to strengthen the general diffusion of innovations. The results suggest that the DSO will benefit from progressing into an advisory role towards end users and others actor within the system.

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Helge Helguson Neumann

List of abbreviations

DOI – Diffusion of Innovation

DSO – Distribution System Operator

EMS - Energy Management System

EVs – Electric Vehicles

NordReg – Nordic Energy Regulators

NVE - Norwegian Water Resource and Energy Directorate

SI – Systems of Innovation

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1 Introduction

An increased presence of innovations and technology in the electricity sector has been motivated by a growing understanding that the current energy system is socially, economically and environmentally unsustainable (Grubler, 2012). The urgency to mitigate fossil fuel emissions has led to a search for more sustainable, efficient and flexible use of energy (Owusu & Asumadu-Sarkodie, 2016). As a result, the transporting sector is undergoing rapid electrification creating higher demand for electricity (FME CenSES, 2015). Together with new appliances with higher power output and a greater complexity among electricity consumers, the growing demand has put increased pressure on the electricity grid (Hafslund, 2018). These challenges are causing a greater need for expensive investments and maintenance of the electrical grid.

Simultaneously, new technologies and innovations create a potential for an improved electrical system, grouped under the term *smart grid* (Ballo, 2015; Gungor et al., 2011; Parag & Sovacool, 2016). The smart grid is utilising technology and innovations such as battery storage, prosumers, smart meters, demand tariffs and energy management systems (EMS). If applied on a large-scale by end users, the smart grid-innovations could be the solution for the challenges in the grid, hence reducing the need for investments (Cardenas, Gemoets, Ablanedo Rosas, & Sarfi, 2014; Naber, Raven, Kouw, & Dassen, 2017). Despite getting mature and competitive on price (Hoppmann, Volland, Schmidt, & Hoffmann, 2014), the innovations included in the smart grid are experiencing a slow diffusion (Furlan & Mortarino, 2018; Negro, Alkemade, & Hekkert, 2012; Römer, Reichhart, Kranz, & Picot, 2012).

Finding correctional measures to diffuse these innovations can provide significant benefits to society. Successful implementation and large-scale application of the smart grid-innovations is associated with greater sustainability, flexibility and efficiency in the system (Gungor et al., 2011; Morgan et al., 2009). Common for the innovations is that they are connected or affecting the electricity grid and must be implemented into the current infrastructure and diffused through the existing system (Haley, 2018). The implementation of smart grid-innovations is therefore dependent on several incumbent actors within the electricity system (de Reuver, van der Lei, & Lukszo, 2016). Hence, the existing electricity system needs to be structured in a way that utilises the potential of the smart grid features (Parag & Sovacool, 2016).

Previous studies on innovations in the electricity system have mainly focused on either the supply-side or end user utilisation (Ghaderi & Tahmasebi, 2014). The distribution system operators (DSOs) role within the innovation system has gained little attention within these subjects. However, the role of the DSOs is arguably important to study when it comes to the diffusion of innovations in the electricity system. Being responsible for the operation and functionality of the electricity grid at the distribution level reveals their centrality as an actor in the pursuit towards the smart grid (de Reuver et al., 2016). The role of the DSO could, therefore, be understood as a *change agent* in the diffusion of innovation (DOI) theory (Rogers, 2003). A change agent role is "one of advocacy, information and implementation support" (Dearing, 2009, p.13) and the DSO is positioned as a key intermediary actor in the expansion of smart grid-innovations (Johansson, Vendel, & Nuur, 2018). Understanding the role of the DSO within the changing dynamic of the electricity system is therefore essential for the socio-economic potential that lies in smart grid-implementation.

The future role of the DSO as a change agent in the Norwegian retail electricity system is especially important to study as the Norwegian Water Resource and Energy Directorate (NVE) is currently planning to implement a *supplier-centric market model*[1] in the retail electricity market[2]. A change in the market model represents a change to the innovation system as it disrupts the linkages between actors. The most significant change with the supplier-centric model is that the power supplier becomes the primary contact point for electricity consumers, contrary to the current retail market model where both DSOs and power suppliers are in direct contact with their customers (Nordic Energy Regulators, 2016). Thus, the communication channel and affiliation between DSO and end users is presumably weakened.

The supplier-centric model reduces the interaction between DSOs and consumers at a time when the consumer is becoming more complex, and the grid is experiencing drastic changes[3]. The overall usage of electricity is expected to increase by approximately 15% by 2025, mostly due to the electrification of the transport industry (NVE, 2018). The increase in the number of electric vehicles (EVs) and new energy-demanding consumer appliances are also leading to higher power output (Hafslund, 2018). Further, the complexity of the electricity

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[1] The supplier-centric market model is sometimes referred to as customer-centric market model or new market model in the literature

[2] https://www.nve.no/reguleringsmyndigheten-for-energi-rme-marked-og-monopol/horinger-endringer-i-lover-og-forskrifter-knyttet-til-reguleringsmyndigheten-for-energi-rme/

[3] https://smartgrids.no/wp-content/uploads/sites/4/2013/11/Meta.pdf

user has increased as electricity consumption patterns have altered, and self-production is causing bi-directional flows of electricity in the system (Johansson et al., 2018). Traditionally, electricity has been flowing one-directionally from the grid to the end user making consumption behaviour predictable for DSOs. However, increased distributed generation, especially in households and industry with solar panels, is creating bi-directional flows of electricity in the grid, which poses challenges for the grid (Pepermans, Driesen, Haeseldonckx, Belmans, & D'haeseleer, 2005). In sum, the changes in the electricity system will likely lead to higher investments in the grid, higher fluctuation in power output and energy usage, and more complexity in the system. The smart grid-innovations introduce a significant potential to resolve these issues and reduce the need for investments (Arnold, 2011).

From a theoretical perspective this thesis is interested in finding out the implications for the role of a change agent when the link to the end user is reduced, and how this affects the diffusion of innovation. The combination of two theoretical perspectives is employed: the systems of innovation (SI) perspective and the DOI theory. While the SI perspective provides an overview of the electricity system as an innovation system, DOI theory looks at particular relationships between actors within the innovation system. This thesis is, therefore, aiming at providing both a systemic macro-perspective and a relational micro-perspective to the understanding of the DSO as a change agent and the implications of the supplier-centric model. Thus, the SI perspective functions as a background for this study, while most of the empirical research relates to the DOI theory. The motivation for the application of two theories is due to the characteristics of the empirical case. The implementation of the supplier-centric model in the retail electricity market is a change at the macro-level which inflicts on the micro-level of the innovation system. Sovacool & Hess (2017) argues that this form of theoretical triangulation may offer a deeper understanding of the research subject. Hence, in this thesis, I will examine the role of the DSO as a change agent following the implications of the supplier-centric market model and how this impact the diffusion of smart grid-innovations.

The principal research question is:

How does the supplier-centric model affect the role of DSOs as a change agent for the diffusion of smart grid-innovations?

The thesis is structured to develop a theoretical framework for analysing the empirical case of the supplier-centric model and smart grid-innovations in the Norwegian retail electricity market and thereby answering the research question. This requires a thorough understanding of the literature and theory in the fields of SI and DOI, as well as useful insight into the Norwegian electricity system to understand the implications of the supplier-centric market model and the status of the smart grid-innovations.

Chapter two displays the theoretical background which forms the framework for my analysis. The theoretical framework for analysis derives from the broad field of innovation studies and will draw upon the SI perspective and DOI theory.

Chapter three discusses the methods used to answer the research question appropriately. The section explains how the research study has been conducted and how the data is gathered and processed. The thesis is a qualitative study based on interviews with actors within the sector and document reviews of relevant research, applicable sector reports and consultation statements by relevant actors.

Chapter four provides the empirical background for the thesis, providing an overview of the Norwegian electricity sector, the supplier-centric model and smart grid-innovations in the system. Chapter five contains analysis and discussion based on the interviews and document review to best answer the research question. Chapter six presents some concluding remarks and reflections on further studies.

Limitations

This thesis is limited to the Norwegian retail electricity market for two reasons. First, the change to the supplier-centric model is of relevance to the Norwegian electricity system as NVE are planning the implementation of the model in the retail electricity market. It is important to underline that the model is not implemented. Thus, the thesis is regarding the potential implications of the model once implemented. Secondly, although the other Nordic countries are committed to implementing the supplier-centric market model, and Denmark already have, the difference in structural, organisational, and institutional settings make a national limitation appropriate. In particular, the resources that make up the Norwegian electricity is different from the other Nordic countries. While the Norwegian electricity almost exclusively comes from hydropower, the other countries have a more diverse production of electricity with a blend of nuclear-, wind-, and coal-based, e.g. (Olje- og energidepartementet, 2016). However, the research will draw upon valuable insights from the other Nordic countries' experiences, and similarly aim to provide useful and transferable insights into other retail electricity markets.

Smart grid-innovations include a variety of new technologies and processes at different levels of complexity. Some innovations require little interrelation among the actors within the innovation system and are easily diffused and implemented into the system. Other innovations are more dependent on the interconnectedness of actors within the system and often complementary innovations. An excellent example of the latter is the combination of battery storage, solar panels, automated smart houses and demand tariffs, which describes a complex and interconnected smart grid-system requiring the participation of several actors. However, other technology novelties that are included in the smart grid-discourse are more directly targeting specific operations within the grid. Sensors, big data analysis and drone technology, are used mainly in the maintenance and optimisation of grid-operation. These technologies do not require the same interaction between actors within the system, and especially not between DSOs and consumers of electricity. For this thesis, I am interested in the smart grid-innovations that are intersecting the end users and other actors of the innovation system, in particular, the DSO. Thus, datahub solutions, such as the ElHub[4], could be considered a smart grid innovation, but is outside the scope of this thesis as it does not directly involve end users. Instead, the innovations investigated in this thesis require communication between actors in the form of a change agent and therefore have a more complex diffusion of innovation-process. Further, the thesis is concerned with innovations adopted by consumers which are dependent on diffusion through the innovation system. Innovations that have reached a substantial mass of adopters are not of interest to this thesis. For this reason, an innovation such as automatic meter reading is not included as it is almost entirely implemented in Norwegian households[5]. The smart grid-innovations examined in this thesis are prosumers, battery storage, demand tariffs and electricity management systems (EMS).

[4] https://elhub.no/
[5] https://www.nymaler.no/

2 Theoretical background

This chapter describes the theoretical background upon which the analytical framework builds. The framework forms the foundation for the research and will be revisited in the later chapters.

There are two main theoretical explanations for the slow diffusion of innovation (Jacobsson & Bergek, 2011). The first explanation is attaining stagnant diffusion to market failures, where misalignments in the market mechanisms fail to elucidate the appropriate prices (Owusu & Asumadu-Sarkodie, 2016). The second explanation relates to the systemic character of innovations, or system failures, which refers to a disadvantageous configuration of actors, rules, infrastructure and their interconnectedness (Negro et al., 2012).

While well-functioning market mechanisms is a plausible explanation for the slow diffusion of innovation, it fails to consider the complexity and interconnection of the smart grid-innovations. Policy efforts within the energy sector have typically been accustomed to reducing market failures (Ballo, 2015; Lund, 2009). While there has been a correlation between policy support and diffusion of smart grid-innovations (Karakaya, Hidalgo, & Nuur, 2015), it has been argued that the entrustment of the future energy regime at the hands of market participant alone can be challenging for the implementation of these innovations (Skjølsvold, Ryghaug, & Dugstad, 2013). This concern is in line with Verbong, Beemsterboer, Sengers (2012) who argue that institutional barriers need to be considered alongside technological and economic barriers. The slow diffusion of the innovations could, therefore, be attained structural misalignment within the innovation system rather than market mechanisms. Correcting the system requires a need for alignment of several actors' interest, policy measures, the introduction of new market platforms and the inclusion of new actors (Musiolik & Markard, 2011).

There has been a thorough examination of electricity system within the field of innovation studies (Hofman & Elzen, 2010; Jacobsson & Bergek, 2011; G.P.J. Verbong & Geels, 2010). In particular, attention to the transition from non-renewable energy sources towards renewable sources, and the innovations and technologies associated with this shift have gained increased attention in the literature. The urgency for a transition, combined with technological possibilities, has generated the discussion and aim for a smart grid, promising more sustainability, efficiency and flexibility in the energy sector. Various approaches of SI theory have been applied to study these ongoing changes and provide insight and policy implications at a macro-level (del Río & Bleda, 2012; Erlinghagen & Markard, 2012; Foxon et al., 2005; Stephens, Wilson, Peterson, & Meadowcroft, 2013). Similarly, studies using the DOI theory have looked at specific smart grid-innovations and their characteristics for developing into the social system (Haakonsson & Slepniov, 2018; Kebede & Mitsufuji, 2017), as well as the end user as a potential adopter of these innovations (Islam, 2014), exercising a micro-perspective. This study draws upon elements of both the SI perspective and DOI theory with the aim of combining the two theoretical perspectives to form an analytical framework. The framework is used to empirically investigate a case in which a structural change at the macro-level potentially affects diffusion of smart grid-innovations at the micro level.

The SI perspective provides the background for this thesis and is beneficial for identifying and accentuate linkages and interactions of actors, institutions and organisations (Jacobsson & Bergek, 2011). The Norwegian retail electricity market function as such a complex and interconnected system with several actors, institutions and organisations. However, within studies of innovation systems, there has been a significant weight on either the system itself or the technologies, rather than the actors within the system (de Haan & Rotmans, 2018). Similarly, the DOI theory has traditionally been researched from the viewpoint of the innovator or end user, and studies that consider the influence of system effects on adoption behaviour have been sought after (Tran, 2012). This thesis will focus on the role of the DSO as a change agent within the retail electricity market, and how a planned implementation of the supplier-centric model affects the macro- and micro-level of the innovation system.

2.1 Innovation studies

This thesis takes place within the broad field of innovation studies. Innovation studies have several central topics, including effects of innovation, measuring innovation, innovation policy and innovation systems (Fagerberg, Mowery, & Nelson, 2005), with the latter being the research area of this thesis. Central to the study of innovation systems is that innovation does not occur in isolation, but rather within an ecosystem of actors involving various elements and influences (Fagerberg, 2005). In the following sections, I will describe the theoretical background and relevance of innovation studies, SI, and DOI.

Innovation is considered a driving force for both economic and social change (Majumdar, Guha, & Marakkath, 2015). Historically, the discipline has close connections to economics, with the Austrian economist Joseph Schumpeter considered to be the primary influencer in the development of the field. Schumpeter started promoting the understanding of innovation as a vital source of economic growth in society more than half a century ago (Fagerberg, Martin, & Andersen, 2013).

Although there are many interpretations and perceptions, a general understanding of innovation is "new creations of economic significance" (Edquist, 1997, p. 1). Innovation itself can be understood in both a narrow and a wider sense (Edquist, 2005). While Nelson & Rosenberg (1993) limited innovation in purely technical terms, referring to technical innovations, Schumpeter himself had a broader understanding of innovation as new combinations of existing products, new products and new organisation (Fagerberg, 2003). Thus, innovations can be both new elements or combinations of existing elements.

Further, there is an essential distinction between invention and innovation. While all innovations are inventions, inventions are not necessarily innovations (Kline & Rosenberg, 1986). An invention can be registered at the patent office a considerable time before it potentially becomes an innovation. Thus, there is often a considerable time lag for an invention transfers into an innovation (Fagerberg, 2005). The time lag is important to underline, because most innovations within the smart grid concept have been available for a long time, but only recently gained extensive attention.

For this study, I will adopt the definition of *innovation* from Dosi (1988, p. 222):

"the search for, and the discovery, experimentation, development, imitation, and adaption of new products, new production processes and new organisational set-ups.".

There are two features of this definition which are pertinent to this thesis. The first is that innovation can be both tangible physical commodities, as well as intangible innovations such as changes to organisational set-up and differences in procedures. Most innovations related to the smart grid are physical, such as battery storage and EMS. However, there are important intangible concepts within the term smart grid that can be considered innovations, such as demand tariffs and flexibility markets. The latter is an intended market platform in which user-flexibility can be bought and sold in order to stabilise and increase the efficiency in the electricity grid at distribution (Eid, Codani, Perez, Reneses, & Hakvoort, 2016). A flexibility market is currently missing from the retail electricity market but is considered a vital aspect of the smart grid concept.

The second significant feature of the definition is that it views innovation as a process, rather than as a static occurrence. Stoneman (Stoneman, 1995, p. 2) coined the process of innovative change as the “Schumpeterian trilogy”. The trilogy consists of three phases of innovation. First is the invention process where the generation of new ideas occurs. The second stage is where the invention develops into an innovation. In this phase, the invention is developed into products or processes ready for market interaction. The last stage is the diffusion stage, in which the innovation spreads across end users.

The Schumpeterian trilogy highlights innovation as a process and as systemic. It also elucidates innovation as an economic driver in a broader sense. Innovation has a societal impact beyond purely economic growth. While profit is often an initial driver for innovation, the solutions often imply positive societal impacts. Innovation in medicine can be profitable for the inventors, but it also improves the living standard of the users. Similarly, innovations in the retail electricity market can be both profitable, but also bring societal improvements such as a more sustainable environment. Thus, the innovation process involves and impacts several actors in the social system.

2.2 Systems of innovation

Innovation is often the result of an extensive process involving various elements and influences (Fagerberg, 2005). A systemic approach is therefore useful to understand the underlying processes for the implementation of innovations in society. The recognition of innovation as a systemic phenomenon has generally been accepted within the field since the late 1980s (Fagerberg, Martin, & Andersen, 2013). Instead of a linear relationship between basic research and applied science, the innovation process is characterised by interaction and feedback between actors of the system (Edquist, 1997). Thus, the elements surrounding the innovation and the actors involved in the process of innovation-diffusion can provide valuable insights into the eventual success or failure of an innovation.

A system consists of multiple elements and the relationship between them (Lundvall, 1992). Further, Edquist (2005) describes a system of innovation as all important economic, social, political, organisational, institutional, and other factors that influence the development, diffusion, and adoption of innovation. Lundvall (1992) argues that the SI perspective needs an open and flexible definition, as it may have different subsystems included in the system, and both the primary system and subsystem are subject to changes. For example, the electricity system would be considered a subsystem of the energy system. Further, the retail electricity market is a sub-system of the electricity system. Hence, changes in the primary energy system will impact its sub-systems. This highlights the connectedness between the energy and electricity systems. Thus, various factors at both system levels, such as economic, social, political, organisational and institutional settings impact the development and diffusion of innovation (Edquist, 2005). It is, therefore, a particular dynamic and processual characteristic to the SI approach.

The SI approach in this thesis is therefore used to describe the innovation system and all elements involved in the innovation-diffusion process of smart grid-innovations. The elements include public and private actors, institutions and organisations which impacts the innovation process. Innovation does not occur out of anywhere, and it is not automatically adopted into society. Further, the thesis views the retail electricity market as an innovation system, in which there is a disruption to the linkage between DSOs and end users. Besides, the change is happening at a time where there is a surge in technical and innovative solutions in the electricity system, conceptualised as the smart grid.

2.3 Diffusion of innovation

DOI theory dates back to the early 20th century and the work of French sociologist Gabriel Tarde (Toews, 2003). The theoretical field was later popularised and developed by Everett Rogers[6]. Following the success of Rogers (1962) book, *Diffusion of Innovation*, in 1962 the theoretical understanding has spread to all major areas of social science as well as interdisciplinary research (Kinnunen, 1996). The DOI field has links to economics, sociology, psychology and anthropology. As with innovation studies, the DOI theory and research has become increasingly more popular in recent decades.

The term *diffusion* relates to the “spreading of social or cultural properties from one society or environment to another” (Kinnunen, 1996, p. 431). Specifically, diffusion of innovation is the process of communicating innovations through communication channels to the members of a

[6] http://cjni.net/journal/?p=1444

social system (Rogers, 2003). Thus, the DOI relates to the ability for innovations to transcend from its origin and into society.

There are generally three types of agents in a DOI network: “Those producing innovations are called innovators, those enhancing diffusion are called change agents and those receiving an innovation are called adopters” (Kinnunen, 1996, p. 438). For this thesis, innovators are relating to third-party actors, and adopters refer to end users/consumers/customers. Third-party actors, power suppliers, and DSOs are all potential change agents as they fall within the definition.

Further, Rogers’ (2003) DOI theory surround four elements which are essential for the success of the innovation: the innovation itself, communication, time, and the social system. An innovation is not necessarily recently invented, but need to be “perceived as new by whomever is adopting it” (Lundblad, 2003, p. 52). For example, the use of sunlight as an electricity source is not a novel invention. The photovoltaic effect, i.e. creating electrical voltage from light, was discovered as early as 1839 and the first solar cell was created in 1883[7]. However, it is over the last couple of years that solar cells have had a surge in popularity (Figure 1) and the idea of solar panels as a source of electricity production in the household is contemporary for most consumers. Despite a recent increase in popularity, solar panels are relatively infrequent among Norwegian households.

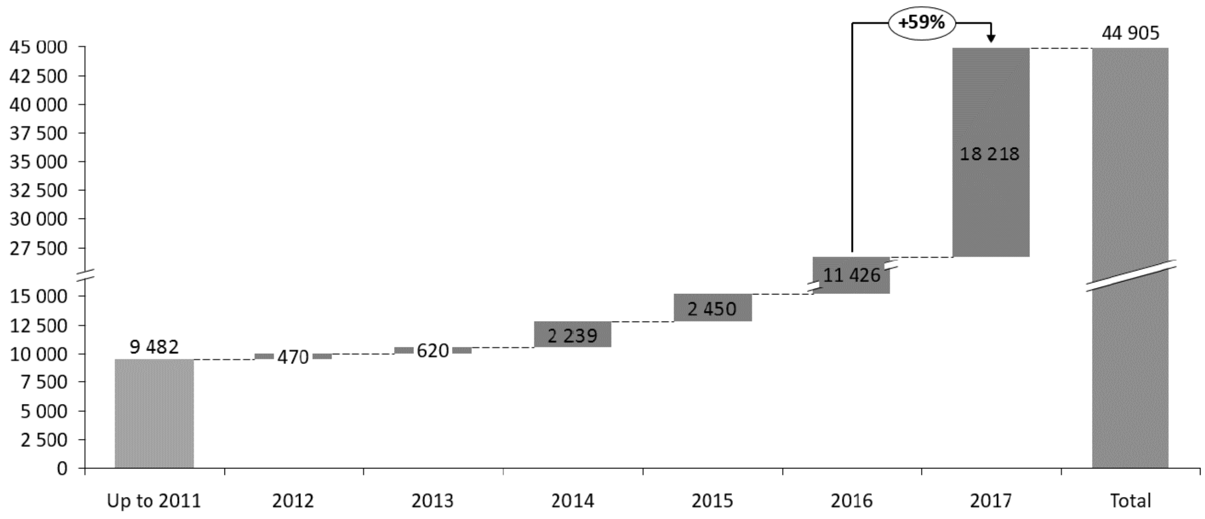

Figure 1 – *Development of installed solar-capacity between 2012 and 2017.* Measured in megawatt peak. Adapted from “Solcellesystemer og sol i systemet” by Multiconsult & Asplan Viak (2018), p.31.

[7] https://www.solarpowerauthority.com/a-history-of-solar-cells/

The second element in the DOI theory is communication. This element focuses on how people develop a joint understanding of the innovation through the advancement and sharing of the innovation (Rogers, 2003). The rate of the process depends on four components: the innovation, a unit (individual or organisation) that knows the innovation, a unit (individual or organisations) that is unaware or does not use the innovation, and a communication channel between the two units. The most common channels are mass-media or direct relationship between the units. Especially, the relationship between the two units in the process is considered crucial as potential adopters often view the merits of the mediator more important than the qualities of the innovation itself (Lundblad, 2003).

Time is the third element of the DOI theory, with three sub-elements: the innovation-decision process, adopter categories and the rate of adoption (Rogers, 2003). The primer is concerned with the process of adoption by the end user, from when the unit is aware of the innovation to implementation or rejection of the innovation. Adopter categories refer to how likely an end user is to adopt the innovation at an early or late stage and should approximate a bell-shaped curve if diffused into society (see figure 2).

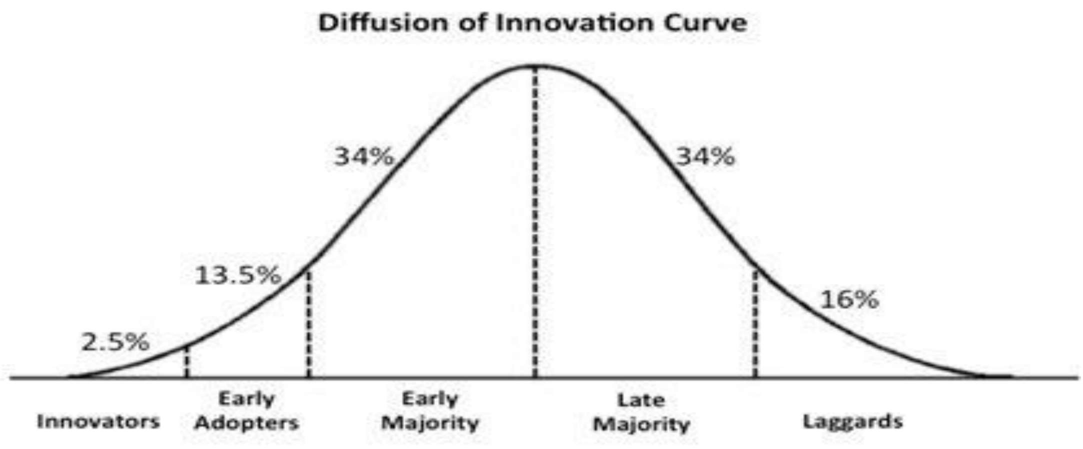

Figure 2 - *Diffusion of Innovation Curve*. Adapted from Rogers (1962) referred to in Moum, Hauge, & Thomsen (2017).

The categories refer to the stage at which the end user adopt the innovations. They are, in order of adoption, as follow:

- Innovators
- Early adopters
- Early majority
- Late majority
- Laggards

The stage of early majority represents what is considered a critical mass for the adoption of the innovations. Further, the stage between early adopters and early majority is considered the most crucial for the successful implementation of an innovation (Moum, Hauge, & Thomsen, 2017). Lastly, the rate of adoption refers to the time it takes for the innovation to become a part of the social system.

The last element of DOI theory is the social system, which refers to individuals, groups, organisations or sub-systems, that share common characteristics that link them together. A social system can be a neighbourhood or all consumers in a country, depending on the scope of the study object.

DSOs as change agents

The role of a change agent has commonly referred to an "individual who influences clients' innovation-decision in a direction deemed desirable by a change agency" (Rogers, 2003, p. 366). Traditionally, the emphasis has typically been on which characteristics of the innovation that make it fail or succeed, or why consumers have adopted or refused an innovation. Although later research has put greater importance on the role of communication between agents in the DOI network (Kinnunen, Jussi, 1996), there remains less attention on the change agent's role in the diffusion of innovation in the DOI literature. In particular, a critique of the traditional DOI theory is that it falls short when analysing complex and networked technologies such as the electricity system (Lyytinen & Damsgaard, 2001). The more complexity and number of involved actors, the more complex the innovation system become. While doing empirical studies on electronic data interchange, a field with similar complexity as the electricity system, Lyytinen & Damsgaard (2001, p. 173) found that DOI researchers need to "understand the role of institutional regimes, focus on process features and key players in the diffusion arena". Thus, looking at the role of the DSO can provide valuable insight into understanding the retail electricity market as an innovation system.

The term change agent can be broader than an individual. Rogers' theory has been criticised for paying too little attention to the role of organisations and focus for the most part on diffusion between individuals (Lundblad, 2003). For example, Rogers' theory does not account for communication through institutional channels, such as journals, regulation, or professional organisations. Nor does it describe innovation diffusion from the perspective of organisations, but rather focus on the innovation-decision process for individuals or within organisations (Lundblad, 2003). A more accurate description of a change agent would, therefore, be a unit or agency which influences a client's innovation-decision process. There are many individuals, organisations and government actors that fit the description of a change agent. For example, both teachers and the school can be considered change agents for the application of educational innovations. Similarly, in the retail electricity market both DSOs, companies and power suppliers can potentially be change agents. What is essential is an influential role for the diffusion of the innovations.

A change agent can be understood as an intermediary actor, an agency "working between actors – producers and users, entrepreneurs and adopters, idea generators and funders" (Kivimaa, 2014, p. 1370). For the DSO, the role of a change agent ties to the role of government-affiliated intermediaries. Government-affiliated intermediaries are organisations such as" quasi-autonomous government agencies, government-owned companies or government-initiated foundations" (Kivimaa, 2014, p. 1371). The electricity market in Norway is characterised by national or regional ownership. The government owns 90% of the production at either state, regional or local level, while most DSOs in Norway are owned, wholly or in part, by local governments (Olje- og energidepartementet, 2016). What characterises a government-affiliated intermediary is that it "fall between traditional public and private sector actors" (Kivimaa, 2014, p. 1371).

Further, government-affiliated intermediaries "provide an alternative or complement to traditional policy instruments but yet differ from business-based intermediaries, whose actions are typically determined by profit" (Kivimaa, 2014, p. 1371). The broader societal perspective of these intermediaries has implications for the incentives of the change agent as they often have to balance an economic yield with greater social responsibility. In other sectors, such as agriculture and health, research has looked at the role of intermediary actors (Kivimaa, 2014). However, this role has also gained little attention in studies of the electricity system. The exception being Karakaya et al. (2014), which have examined the role of government and local solar companies as potential change agents. The findings suggest that these actors are a valuable driver for adoption and that there are several motivators for adoption beyond economic benefits. Thus, the DSO fit the description of a government-affiliated intermediary and could be understood to represent both commercial and social aspirations.

One characteristic of the change agent is that they "usually possess a high degree of expertise regarding the innovations that are being diffused" (Rogers, 2003, p. 368). Innovations can be challenging to understand for end users as it is often associated with high technical competence. Hence, the change agent functions as a bridge between the innovation and the consumer, where the success of the diffusion can depend on the ability of the change agent to communicate its attributes. Large volumes of information can lead to *information overload*, while the inability to communicate the ability and benefits of the innovation potentially leads to rejection of the innovation (Rogers, 2003, p. 368).

There are other potential change agents within the retail electricity market. Third-party actors who benefit from the adaption of a particular innovation have incentives for large-scale applications by the end user. Power suppliers are also a potential change agent as they could include smart grid-innovations as part of their service to attract customers. Power supplier operates with a small profit margin due to the high competition in the market, at times with a negative profit margin to attract customers[8]. Therefore, a subscription including benefits from smart grid-innovations could be attractive for the consumers and give these companies a competitive advantage. User-friendliness and competition on service are some of the motivation for the shift to a supplier-centric model (Nordic Energy Regulators, 2011). The government and regulator also function as potential change agents as they can influence much of the formal institutions that govern the innovation system and therefore the diffusion of innovation. However, the main consequences of the supplier-centric model affect the DSO's role towards customers, which is the rationale for limiting the study to this unit.

From the DOI theory, it is especially the two elements of communication and time in which the role of the change agent is particularly influential. The communication element relates to the relative strength of the communication channel and the relationship between two units (Rogers, 2003). Within the time element, it is particularly the innovation-decision process where the change agent is relevant in persuading the end user in a desired direction of the agency. However, the adopter categories and the current status of the diffusion of the smart grid-innovations is relevant for the understanding of the rate of diffusion of these innovations.

[8] https://www.distriktsenergi.no/artikler/2017/5/22/nytt-regelverk-kan-gi-nye-muligheter-for-stromkunder/

2.4 Framework

The background of the SI perspective and the DOI theory provides a good starting point for the construction of an analytic framework. The framework needs to account for the complexity of the retail electricity system as an innovation system. Further, there is a need for the framework to emphasise the role of the change agent for the diffusion of smart grid-innovations.

The framework is used to evaluate the strength of the DSOs position towards the end user, implicitly looking at the positional strength of the DSO as a change agent in the innovation system. The *innovation-decision process* is defined as

"the process through which an individual (or other decision-making unit) passes from gaining initial knowledge of an innovation, to forming an opinion of the innovation, to making a decision to adopt or reject, to implementation of the new idea, and to seek confirmation of this decision" (Rogers, 2003, p. 168).

However, the framework is not an evaluation of an individual's innovation-decision process, but rather the effects of the change agent's relation to the end user's process of adopting innovations. Rogers identified five stages in the process, which are:

- Knowledge – potential end users are introduced to the innovation
- Persuasion – potential end users form an opinion about the innovation
- Decision – potential end users adopt or rejects the innovation
- Implementation – the innovation is put into use by the end user
- Confirmation – the end user seek confirmation about the adoption of the innovation and decide whether to reverse the decision or not

The framework applied in this thesis will concentrate on the stages of knowledge, persuasion and implementation, which are the stages in which the DSO as a change agent has a greater influence on the diffusion of innovation. Figure 2 displays the actors within the retail electricity market and their relation concerning the innovation-decision process. Knowledge is closely related to the spread of information about new technologies, educating the users about the innovations, their abilities and characteristics, and is where the "change agents could play their most distinctive and important role in the innovation-decision process" (Rogers, 2003, p.

173). Persuasion is concerned with incentives for the users to adapt and implement to the innovations. At this stage, the end user will be looking for personal advantages or disadvantages. The stage is closely related to the knowledge stage but is more emotional rather than cognitive in evaluating information (Rogers, 2003). Thus, the change agent's behaviour, trustworthiness and perception by the end user can influence the persuasion stage. Implementation is the adoption of innovations and "involves behaviour change as the new ideas are actually put into practice" (Rogers, 2003, p. 179). The stage usually follows directly after the decision-stage, and often demands a specific competence from a system actor.

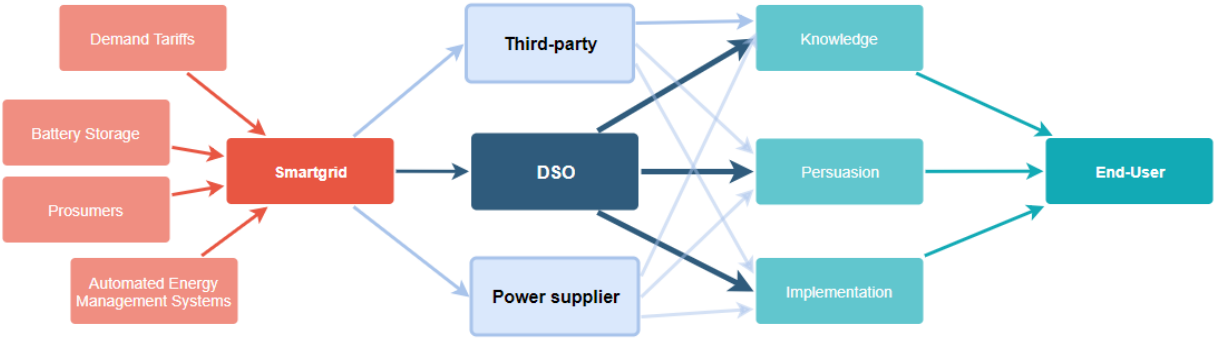

Figure 3 - *The retail electricity market as an innovation system*

While the decision and confirmation stages arguably can be influenced by other actors of the system, they are individual in nature. The stages applied in the framework are affected by the direct linkage between the change agent and the end user. Thus, the research aims to provide insight into how the supplier-centric model affects the innovation-diffusion in the three primary relational stages, knowledge, persuasion and implementation.

3 Methodology

In this thesis, I am looking for interpretations, perspectives, understandings and opinions about the role of the DSO, the supplier-centric model and its impact on the diffusion of new technologies and innovations. I intend to go in-depth in the retail electricity market to be able to answer the research question put forth in the introduction. To get a more profound understanding of the subject, I will argue that a qualitative study is best suited. This chapter addresses the methodological choices made in the thesis and how data was gathered and processed. Further, I will argue for the reliability and validity of this study.

This study is part of a research project called *The future grid*[9], which is coordinated by Adapt consulting[10] and aims to raise the competence of actors within the retail electricity market with regards to the future electricity grid. The project group consists of ten DSOs, one industry association and one consulting firm and have provided guidance and feedback at the beginning of this research.

3.1 Qualitative studies

Qualitative studies are concerned with finding out *how* something is done, interpreted, said, used or developed, contrary to quantitative studies that focus on *how many* or *how much* (Brinkman & Tanggaard, 2012). The qualitative study is an "interpretive approach concerned with understanding the meanings which people attach to phenomena" (Snape & Spencer, 2003, p. 3).The supplier-centric model is one such phenomenon that requires interpretation and understanding rather than quantitative measures to evaluate its impact on the retail electricity market and the consequences for the diffusion of innovation. The complexity of the electricity system as a system of innovation makes a qualitative study more appropriate for this type of research. Further, the supplier-centric market model is only in the planning stage of implementation, which makes the nature of the study theoretical and assumptive as actual observations cannot be made until the is implemented. However, the study is valuable for understanding potential consequences in advance based on the understandings of proficient people in the sector, and an understanding of the position of the DSOs as change agents for diffusion of innovation.

[9] Translated from Norwegian, "Fremtidens nett", own translation
[10] http://adapt.no/

The methodology used in the thesis is a toolkit to best answer the research questions. There are many possible ways of conducting a qualitative study depending on the study object (Johannessen, Tufte, & Christoffersen, 2010). For this study, I have chosen to use document analysis and expert interviews. The interviews will give primary documentation of perceptions about the dynamics of the retail electricity market and expectations about the future. The document analysis will give a good overview of the intentions and consequences behind the supplier-centric model as well as a better understanding of the electricity sector and the actors within the system. Combined, these will give an overview of the DSO position as a change agent, the supplier-centric model and a better understanding of the changing dynamics in the retail market for electricity.

The study is phenomenological in its approach. Phenomenology is used as an approach to research and describe individuals and their understanding of a study object (Johannessen et al., 2010). Thus, the *meaning* of the phenomenon is a critical aspect of the research. In a phenomenological study, this study is conducted to comprehend the respondents understanding of the dynamics of the retail electricity market, the role of the DSO and the potential impact of the supplier-centric model.

3.2 Data collection

There has been continuous interconnectivity between the document analysis and expert interviews. The electricity market is changing rapidly, and new and relevant documentation have appeared throughout the work with the thesis. Similarly, insights from the interviews have shed new light on information in documents read in advance. Thus, there has been a dynamic development in the thesis throughout the process to improve the quality of the research. I have had to re-evaluate the thesis structure and framework at times to best provide the setting to answer the research questions. This constant assessment has led to a progression in the interview guide as new information from the interviews has made certain aspects more relevant than others. It has not been a mission to procure unanimous acceptance of any opinions or position about any subject or arguments to deem them accurate. Instead, differences of opinion illustrate the contention of the subject.

3.2.1 Document analysis

The documents analysed can be divided into two broad groups of literature. The first is the relevant academic theory which encompasses research on innovation systems, diffusion of innovation, smart grid literature and electricity market design studies. These readings are primarily used to understand the retail electricity market as an innovation system, the smart grid concept and innovations, and the role of the DSO as a change agent. The second group of literature is relevant documents from the energy sector, concerning recent changes in the industry, the setup and intention of the supplier-centric model and predictions about the electricity market. This literature includes reports, official documents and consultation reports and responses. By linking the two types of documents, together with expert interviews, I will get a comprehensive overview of this complex sector. In addition, I have attended two conferences: *Smartgridkonferansen 2018*[11] and *Nettselskapenes økonomi, effektiv drift og investeringer*[12].

Relevant documents were retrieved through various literature searches at Google Scholar[13] and UiO:Oria[14] containing relevant subjects and concepts. Further, sector reports were obtained by going to websites of actors within the retail electricity market such as Nordic Energy Regulators (NordReg), NVE and Energi Norge, as well as reports from DSOs and power suppliers and energy consultancy agencies. In addition, I subscribed to five relevant newsletters: Energi Norge, Distriksenergi, EnerWe, Energi & Klima and NVE. Additional document resources have appeared throughout the work with this thesis by discussions with informants and through seminars and lectures.

3.2.2 Expert interviews

Together with the document analysis, the expert interviews are used to get a deeper understanding from people within the sector. The respondents were recruited with assistance from the energy consultant firm Adapt Consulting, which are coordinating the research project this thesis is part of. I was granted a list of possible candidates which I then contacted by e-mail at the beginning of June 2018. Based on three preliminary conversations with industry experts, together with an initial reading list, I decided to get perspectives from

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[11] The Smart grid conference 2018, own translation
[12] The DSOs' economy, efficient operation and investments, own translation
[13] https://scholar.google.no/
[14] https://uio.oria.no

various actors within the market with differing interests and capabilities to cover the broadest possible aspects within a limited time-frame. I was aiming for four to eight respondents from organisations with different attributes and perspectives.

Based on the response from the potential candidates I arranged six interviews with various representatives from the sector including CEOs of DSOs, employees within research and strategy departments of DSOs, two representatives from the regulator NVE and a consultant from an industry association. The group of interviewees falls under the concept of a *techno-epistemic network* which is “a network of professionals with recognised expertise and competence in a particular domain and an authoritative claim to policy-relevant knowledge within that domain or issue-area” (Haas, 1992, p. 3). The background of the respondents gives strengthen value to their explanations and understandings of the subjects discussed.

The interviews were conducted between June 9th and September 3rd of 2018. All interviews were recorded on an audio device with the permission of the interviewees. The different characteristics include the size of the organisation, position in the retail electricity market, position of the interviewee, and the relative competition among suppliers in the area. I have adapted NVE’s classification of DSO size which labels DSOs above 60,000 customers as large and DSOs with 6,000 to 60,000 customers as mid-sized (NVE, 2017b). The DSO respondents reported the level of supplier competition within their concession area. There was no response from candidates representing small DSO. The lack of small-sized DSOs within the study is unfortunate as it would have given a more comprehensive understanding of the sector. However, the respondent from the industry association represented a fair amount of smaller DSO which offers some perspective on their standpoint.

The interviews were conducted in a semi-structured manner with both open-ended questions and a few close-ended questions. A semi-structured interview allows for a certain structure as well as flexibility to investigate certain subjects further, if deemed necessary (Johannessen et al., 2010). From an initial reading list and the three preliminary conversations with industry representatives, I developed an interview guide consisting of five subject areas: organisation, supplier-centric model, customer contact, the future of the (smart) grid, DSO adjustments for the future. Within each subject, there was a set of questions and keywords, mainly open-ended to try to guide the conversation towards new and relevant findings. I allowed myself the freedom to modify questions and add further questions during the research period, based on new information from the respondents and other sources. During the interviews I took notes to follow up on statements later in the interview, or cross-reference with other sources at a later stage. The respondents were not informed about any theoretical concepts as this was not relevant for their response and would require a particular understanding of the field of innovation studies.

The interviews were conducted in Norwegian and lasted between 51 and 61 minutes. Table 1 displays a list of the interviews and characteristics of each respondent. Four interviews were held face-to-face, while the other two were conducted through Skype. All interviews were translated into English afterwards. Hence, citations in the thesis are translated from Norwegian to English. From the six interviews I felt that the data collected was sufficient for this study and did not pursue further respondents.

Table 1 - *List of interviews*

Organisation	**Name in thesis**	**Position of interviewee**	**Duration**	**Supplier competition**
Mid-sized DSO	DSO 1	CEO	61 mins	Low
Large-sized DSO	DSO 2	Department manager	54 mins	High
Mid-sized DSO	DSO 3	CEO	52 mins	Low
Large-sized DSO	DSO 4A & DSO 4B	Department manager & department manager	55 mins	Low
Regulator	REG 1A & REG 1B	Senior Consultant & Consultant	59 mins	N/A
Industry association – representing small- and mid-sized DSO	IND 1	Consultant	51 mins	N/A

3.3 Data analysis

The interviews transcribed in Norwegian amassed to 55 pages of raw data material. During the first readthrough, keywords were identified and categorised based on concepts from the previous chapters. I then marked useful citations and arguments which were grouped within the three stages of the framework: *knowledge, persuasion and implementation*. Statements which would fall outside these stages or within several of the stages were grouped as *other* or given separate headlines. Knowledge for the end user is closely related to the ability of the change agent to communicate information about the innovations. Thus, arguments about the position of the DSO to communicate smart grid-innovations were placed in this category. Persuasion for the end user is closely related to incentives, and especially price-signal and cost-efficiency for the end user. Thus, arguments about the position of the DSO to elucidate price-signal and other incentives are placed into this category. Lastly, implementation for the end user is about receiving adequate assistance and competence to utilise the smart grid-innovations. Thus, arguments about the DSOs competence and position in the implementation of the innovations is gathered within this category. This same grouping was done with the documents analysed during this research. Documents were also categorised into other relevant themes for the thesis, such as the four smart grid-innovations.

3.4 Reliability & validity

Reliability and validity are used to evaluate the quality of a study (Ringdal, 2013). The concepts developed in natural sciences, mostly concerned with quantitative research and their ability to generalise findings from a sample onto a larger population. Because of these concepts' historically close connection to tangible and measurable results, their relevance in qualitative studies has been questioned (Ritchie & Lewis, 2003). While an experiment in physics or mathematics can be reproduced and tested straightforwardly, qualitative studies are fashioned in a way that reproducing the exact study is either irrelevant or unattainable. Often the study objects are too unique or too complex to for the study to make generalisations. However, if we adopt a broader understanding of the terms and relate reliability to sustainability and validity to precision the concepts increase in relevance and ability to generalise findings (Ritchie & Lewis, 2003).

Reliability and validity are applied to justify the sampling and evaluation of data and rationalise the findings in a reasonable measure. Further, the data should reflect the reality of the study object, and not be altered to provide potentially more exciting results or be well-suited to a specific conclusion. Thus, reliability and validity will be an assessment that the study is done with accuracy, that the findings and methods are useful in similar studies and that the study has been conducted rationally. Just as important, the researcher should reflect on the methods not pursued, choices rejected, limitations in data gathering and other possible explanations for the findings.

Reliability

Reliability is used to assess whether an equivalent study, using the same inputs, can produce the same result (Yin, 2014). This chapter has explained the methodology, giving guidance to how the study was conducted and why these steps were taken. By doing so, other researchers are enabled to replicate the study, giving reliability to the research. The documentation of procedures is especially important for the ability to reproduce the study (Yin, 2014). To increase the reliability, I have attached an interview guide (Appendix I) and a list of interviews earlier in this chapter. This transparency allows for similar studies to be conducted using identical methods and approaches.

The nature of interviews and phenomenology can be problematic due to interpretive bias. Asking and answering questions are inherently open for different interpretations and there is not always a mutual understanding between the researcher and the interviewee (Silverman, 2000). Often the reader must depend on the researchers understanding of the interviewee's statements. To avoid this form of bias I have tried to reduce any misunderstanding of concepts, explanations or questions by following up with additional clarifying questions.

While interviews expose potential interpretive bias, it also creates an additional dimension that can strengthen the data. By doing audio-recordings and face-to-face interviews, it is possible to understand nuances in tone and body language, thereby getting a better understanding of what is being conveyed. These features are missing in text material, and the interviews give the possibility to follow up on these detections, potentially revealing relevant information. By interpreting changes in tone and body language, I have been able to further pursue subjects that have stirred emotions among the respondents. Thus, the importance of conducting the interviews to promote reliability rather than reduce it has been a focus area in the research.

Validity

"Validity is another word for truth" (Silverman, 2000, p. 175). In scientific research, the concept reflects on how accurate or precise the research findings are (Ritchie & Lewis, 2003). In other words, it is about getting the researcher and readers to realise that the results are based on critical investigation rather than well-chosen examples or a lucky draw. The main question a qualitative researcher must ask is whether the research is accurately reflecting the study object as perceived by the study population (Silverman, 2000). Thus, the validity refers to the quality of the study sample more than anything.

Validity can be further divided into internal and external validity. Internal validity refers to the correlation between the study sample and reality, and whether the research being done correspond with the research intended (Ritchie & Lewis, 2003), while external validity refers to the findings' ability to be applicable in other context or settings.

To increase validity to arguments in the study, I have used the method of triangulating findings (Yin, 2014). Triangulation involves finding support for arguments through several sources. The sources used in this study are academic literature, reports, interviews, hearing notes and responses. One problem with triangulation is when the use of multiplicity is used as a method to settle doubts about validity. With many varying views on a subject it can be simple to find documents supporting a statement, and thus take this as a form of cementing the argument. As with any dispute, the researcher should explore varying views and possibilities, look for biases and try to validate each statement. During the research there were differences of opinion amongst the respondents. It has been my intention throughout the study to remain objective and avoid any bias towards either side of any dispute.

In this research, I have tried to give validity to statements and arguments that can be found across various sources, whether it is several interviewees or documents, or a combination. Further, I have added opposing views where appropriate. Much of this thesis involves opinions about the future of the electricity system, and there is a fundamental uncertainty to the arguments. Rather than predicting the truth, it is more important to evaluate the strength of the arguments, and how documented and reasonable they are.

In conclusion to this chapter, I would argue that this study has validity and reliability due to its ability to be related to other context or settings in two ways. First, it gives the ability to replicate the study to find similar findings within the electricity sector. Conducting this research with other experts within the industry would likely produce similar answers and conclusions. Second, on a theoretical level, the study gives a framework for conducting studies on the diffusion of innovations in similar contexts, where there are a monopolist actor and consumers.

3.5 Ethical considerations

This research contains information about individuals which makes it mandatory to notify the Norwegian Data Protection Services. The notification was done on the 27th of February 2018 and approved in time for the interviews. All respondents received information about the interview and the purpose of the research before the interviews, and the opportunity to withdraw from the study at any time. Further, all respondents were informed that their personal characteristics would be anonymised and signed a permission form to allow for a recitation of their statements and arguments in this thesis. The respondents were informed that attributes about their position within the organisations and other information about the organisations would be disclosed in the thesis.

4 Empirical background

The electricity grid in Norway has 2,9 million access points and connects approximately every household and business in the country. The Norwegian consumers are among the top users of electricity in the world, in large part due to the abundant water resources which have led to low electricity prices[15]. The country's geology, with many moderate-sized mountains where rainfall at high altitude generates energy through the flow of water into waterfalls and watercourse, allow for a rich accumulation of water to be used as a power resource. Since its origin, the electricity supply in Norway has been based almost exclusively on hydropower (Ballo, 2015) and today around 96-99% of electricity production in Norway comes from this energy source[16]. Further, the electricity system is composed of a large infrastructure consisting of centralised production plants and around 130,000 kilometres of power lines (Olje- og energidepartementet, 2016).

The Norwegian electricity sector is divided into two sub-markets, the wholesale electricity market and the retail electricity market. The wholesale market is where electricity is traded between power suppliers, producers and large industry actors. The trading of electricity as an asset goes through an electricity exchange called the *Nord Pool*, where power suppliers buy and sell electricity at market values. Some industry actors are directly operating on the *Nord Pool* exchange or directly connected to a power production plant. Power suppliers then sell the electricity to consumers using a subscription model. This thesis will concentrate on the retail electricity market as the supplier-centric model is a change to the structure of this segment.

The retail electricity market is an essential economic and social part of society. In a country like Norway, elongate and with lots of mountains and cost, infrastructure can be costly. The 130,000km of power lines within the sector is distributed through air, sea and ground, which need maintenance, upgrades and expansion over time. These costs are allocated to consumers through grid-tariffs and a price on electricity usage. The market design is therefore important for the economy of the market, and inefficiencies can be costly for society (Cramton, 2017).

[15] https://www.ssb.no/energi-og-industri/artikler-og-publikasjoner/pa-verdenstoppen-i-bruk-av-strom
[16] https://www.statkraft.no/Energikilder/Vannkraft/;
http://lvk.no/LVK/Fagomrader/Vannkraftproduksjon/Nokkeltall---Oversikt-over-konsesjonssystemet-for

4.1 Actors in the retail electricity market

The three central actors within the Norwegian retail electricity market are the consumers, the DSOs and the power suppliers. The power suppliers are buying electricity from producers or traders and selling it to consumers through subscriptions. This part of the market in Norway is characterised by being very price-sensitive. Norway is consistently having one of the highest rates of switching electricity providers among the Nordic countries (S. Annala & Viljainen, 2009). In addition, third-party actors deliver products to consumers that are often connected to or affecting the grid, such as solar panels or EMS, and therefore has a role in the retail electricity market.

The electricity is delivered through the power grid which is operated by the DSOs at the distribution level. The distribution level represents the lowest of the three transmission-levels in Norway and is where electricity is connected to most consumers. The DSOs in Norway are responsible for the physical supply of electricity to household and businesses, including new connections in their area of concession. Their responsibilities include the operation, maintenance, and investments in the grid. They are also responsible for tariffs and billing regarding grid cost[17]. Due to the country's geography and operating environment, grid tariffs differ from region to region. The size of the grid companies varies as well, from just a few hundred customers to more than hundred thousand (NVE, 2017b). There are 131 DSOs in Norway, ranging from around 700,000 to 15 subscribers (NVE, 2017), which makes the share of DSOs relatively high in Norway compared to other European countries (S. Annala & Viljainen, 2009).

For consumers it is not possible to change DSO, and there is only one DSO per concession due to the cost-inefficiency of having competing operators in one area[18]. The DSOs are therefore considered a natural monopolistic actor and obligated to give access to anyone requesting it within their concession area. Due to the monopolistic nature of the grid-operation, DSOs also has limitations on how much they can charge in grid-tariffs from their customers. This area of the electricity system is highly regulated by NVE to achieve a high-quality distribution of electricity at a low cost and abstain the DSO from doing any commercial activity. NVE governs the revenue cap that grid-operators have. If an operator goes above or below the revenue cap, this is adjusted into lower or higher grid-tariffs for the

[17] https://lovdata.no/dokument/SF/forskrift/1999-03-11-301#KAPITTEL_1
[18] https://www.nve.no/stromkunde/om-kraftmarkedet/

consumers in the following years[19]. This incentivises internal competition among the DSOs as inefficient operation is unfavourable.

The consumers are the end user of the electricity. They are typically households, agriculture and industry actors (Olje- og energidepartementet, 2016). The distribution among the different types of end users varies across the country. Highly populated cities have a majority of household customers, while smaller cities and towns built around one or more industries will have a higher share of the electricity distribution in these sectors. The type of consumer also differs within areas. For example, in the capital Oslo there are a lot of large apartment buildings using relatively small amounts of electricity, while in less dense areas with more agriculture, the usage profile is different. Thus, there are several differences among consumers and geographical variances that need to be recognised.

Traditionally, the electricity consumer in Norway has had little interest and knowledge about the electricity sector, despite having economic incentives to gain more awareness (von der Fehr & Hansen, 2010). Customer participation in the electricity market is expected to increase as new business models have to be developed to account for self-generation, the possibility for consumers to sell back excess capacity and bi-directional flows of electricity (Cardenas et al., 2014). Greater consumer participation is also regarded as a requirement for a well-functioning smart grid.

There are also other prominent actors influencing the retail electricity market. One such actor is the Norwegian government which, in particular, affects the transition towards renewable energy and the electrification of the transporting sector with several policy measures. The government can influence the retail electricity system both through politics and agency. NVE was established in 1921 to take care of the government's interest in hydropower. The organisation is currently under the administration of the Ministry of Petroleum and Energy. NVE is the successor of the *Canal-direction for Danmark-Norge*[20] and *Kanalvesenet*[21] showing the historical connection to channels and water resources[22]. For the retail electricity market, NVE is responsible for regulating the DSOs and setting up institutional settings for competition among power suppliers and third-party actors.

[19] https://www.nve.no/stromkunde/nettleie/
[20] The directory of channels for Denmark-Norway, own translation
[21] The bureau of channels, own translation
[22] https://www.nve.no/om-nve/vassdrags-og-energihistorie/nves-historie/

Third-party actors in the retail electricity market are actors which provides a service or product within the sector outside of the other actors' scope. Suppliers of technologies and innovations within the smart grid concept, such as solar panels or EMS, are examples of third-party actors. These actors have an increasingly prominent role towards the consumers as the smart grid becomes more relevant. Third-part actors are also providing services and products to DSO and can function as an intermediary for certain services within the grid system.

Figure 3 summarises the main actors in the retail electricity market and displays the complexity of the sector. The red arrow between DSO and end user displays the main effect of the supplier-centric market model, which is reduced contact between the two actors.

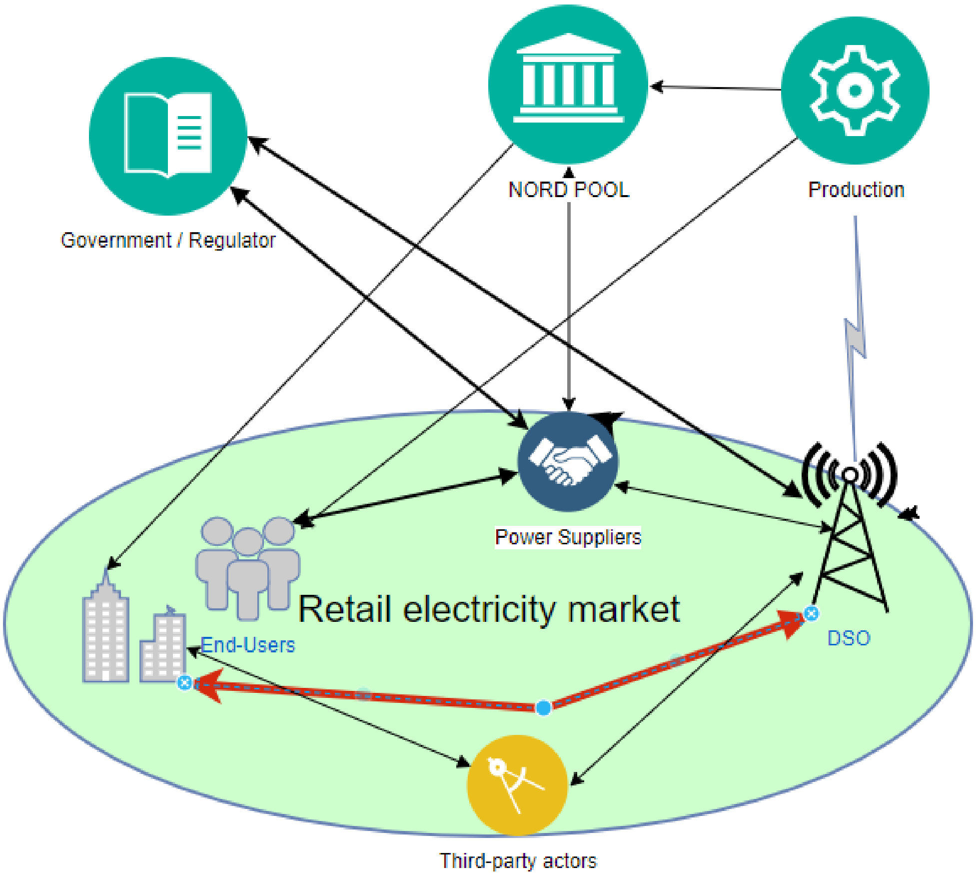

Figure 4 - *The Norwegian retail electricity market*

4.2 The Supplier-centric market model

There have typically been two market models for the retail electricity market and customer interaction (see figure 4). The difference relates to invoicing and meter arrangement (S.

Annala & Viljainen, 2009). The current Norwegian model is based on a triangular flow of information, billing and currency. In the traditional model, the consumer receives separate billings from DSOs and power suppliers and pay separately. The data about metering levels flows from consumer to DSO to power supplier, while the customer contact is direct to and from the customers and the two actors.

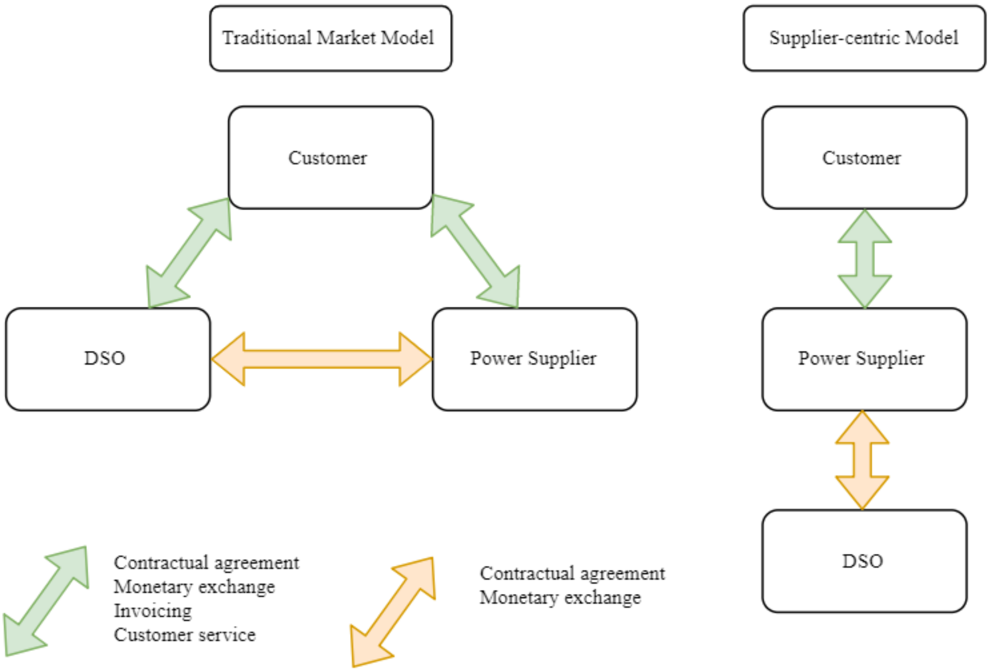

Figure 5 - *Simplified market models for the retail electricity market*.

NVE is currently planning the implementation of a new market model[23]. The new model is a supplier-centric model, which means the supplier is the primary contact for consumers, contrary to the current market model where both grid operators and power suppliers are in direct contact with their customers. The rationale for this switch is to increase competitiveness among retailers and make communication between the commercial actors and consumers easier (Nordic Energy Regulators, 2016). At the same time, it will lead to less interaction between the DSOs and the consumers.

The supplier-centric model represents a change to the retail electricity market structure. NVE initiated the process towards a supplier-centric model in 2016, by advocating voluntary

[23] https://www.nve.no/reguleringsmyndigheten-for-energi-rme-marked-og-monopol/horinger-endringer-i-lover-og-forskrifter-knyttet-til-reguleringsmyndigheten-for-energi-rme/

combined billing through the power supplier[24]. A transition to the supplier-centric model means that the DSO bills the power supplier for the consumer usage, and then the power supplier adds on its bill before sending it out to the customers. With the supplier-centric model this will be mandatory, completely removing billing as part of the DSO role towards consumers. Thus, the supplier-centric model disrupts the flow of payment, billing and customer contact by creating a bi-directional chain from DSO to power supplier to consumer. The grid tariff billing has traditionally been a form of customer contact between the DSO and their customers[25]. The DSO has sent out information alongside the tariff bill as well as information about consumption and contact information.

The change towards a supplier-centric model dates back to 2005 when NordReg began the process to harmonise the Nordic electricity retail markets. The ambition was to create a lower entry-barrier for suppliers to operate in all Nordic countries, increasing competition among the suppliers and lowering the consumer prices (Nordic Energy Regulators, 2011). In 2013, the organisation agreed on a mutual recommendation for the Nordic electricity retail markets to pursue a supplier-centric market model with obligatory combined billing and the power supplier as the primary contact point for customers (Energi Norge, 2018). As of 2018, Denmark is the only country with a fully implemented supplier-centric model. However, they are experiencing difficulties with the model due to issues such as universal coverage and contractual agreements (Energi Norge, 2018).

Supplier-centric models are not uncommon for markets that rely heavily on initial infrastructure investments, such as railways of telecommunication. Typical for these markets is that there is a regulated monopolist responsible for the maintenance and development of the infrastructure, while there is an open competition among several actors providing services connected related to the infrastructure. With free market access, it is expected that actors will compete and innovate to gain customers.

The switch towards a supplier-centric model is in line with the NVE strategy to reduce DSO involvement in commercial activities and instead cultivate their role as facilitators for a well-

[24] https://www.nve.no/reguleringsmyndigheten-for-energi-rme-marked-og-monopol/sluttbrukermarkedet/fellesfakturering-og-ny-markedsmodell/
[25]http://energinorge.nsp01cp.nhosp.no/getfile.php//NYHETER/MARKED%20OG%20SALG/Posisjonsnotat_markedsmodell_for_sluttbrukere_Energi_Norge.pdf

functioning grid[26]. It is not an expectation from NordReg or NVE that all customer contact will vanish between DSO and end user. The DSOs will remain the point of contact in "strictly network related issues, meaning issues that deal with the physical connection or the meter" (Nordic Energy Regulators, 2011, p. 9).

Although, the new market model is likely to be applied within the next few years, there are certain aspects of the supplier-centric model that are unresolved. For one, the question of who should be responsible for the universal service needs to be clarified. Further, NVE has previously stated that the supplier-centric model needs to be implemented together with an operative ElHub, which is currently under development (Energi Norge, 2018).

4.3 Smart grid-innovations

The smart grid is a concept grouping several new technologies and innovations that can increase efficiency, reliability, safety and flexibility in the electricity system. The European Commission[27] defines the smart grid as:

> *"an electric network that can cost-efficiently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety"*

It is believed that the diffusion and implementation of the smart grid and its technologies will provide benefits along the energy value chain (Naber et al., 2017). Users have the potential to lower their utility cost from own production, shift in consumption or to reduce the peak power outtake. Increased flexibility and efficiency reduce DSOs' cost of maintenance, power outages, and allows for greater controllability of the grid. In Norway, the smart grid has also been promoted as a vital source for flexibility and efficiency within the electricity grid. Energi21 (2014), a governmental strategic initiative, concluded in their report *Nasjonal strategi for forskning, utvikling, demonstrasjon og kommersialisering av ny energiteknologi*[28] that there was a need for greater attention to innovation and the smart grid in the future.

[26] https://www.nve.no/reguleringsmyndigheten-for-energi-rme-marked-og-monopol/sluttbrukermarkedet/selskapsmessig-og-funksjonelt-skille/
[27] http://s3platform.jrc.ec.europa.eu/smart-grids
[28] National strategy for science, development, demonstration and commercialisation of new energy technology, own translation

Smart grid technologies can be split into three categories: generation, transmission and distribution (Cardenas et al., 2014). While the first two categories are typically concerned with a limited number of participants, smart grid technologies at the distribution level have more participants involved. This increased complexity has led to a slower evolution, improvement and thereby implementation of these technologies (Cardenas et al., 2014). Smart grid-innovations at the generation and transmission levels are typically concerned with better management and operation of the grid, and therefore dependent on the application of a single user such as the producer or the DSO. However, increased flexibility, efficiency and sustainability are highly reliant on end user's adoption of new technologies, processes and changes in behaviour. Thus, there is a need for diffusion of smart grid-innovations through the retail electricity market to consumers which has not occurred so far.

Four of the main smart grid-innovations believed to impact the electricity system in the near future, subject to adoption by consumers, are prosumers, demand tariffs, battery storage and EMS. These innovations have benefits related to flexibility and shifts in consumption. Further, it is especially the interconnectedness of these innovations which brings optimism for the smart grid. For example, prosumers utilising distributed generation, such as solar panels, have shown low benefit on the electricity system but can provide both flexibility and efficiency if applied together with batteries (Vestby & Dvergnes, 2017).

4.3.1 Prosumers

A *prosumer* is an end user which both produce and consume electricity and is, therefore, a bi-directional user and producer of electricity (Hansen & Hauge, 2017). The prosumers are connected to a source of distributed generation which is defined as an "electric power source connected directly to the distribution network or on the customer side" (Ackermann, Andersson, & Söder, 2001, p. 201). The types of distributed generation are both based on fossil fuels and renewable energy sources (El-Khattam & Salama, 2004). The most common examples of distributed generation are solar panels (also known as photovoltaics), micro-wind turbines, combined heat-and power-installations (CHP), ground source heat pumps and biofuel boilers (Ruggiero, Varho, & Rikkonen, 2015). In Norway, the most common are solar panels, CHP and ground source heat pumps, which has steadily increased over the last decade, much due to the political landscape and attention to climate change. It is a consensus that the energy system in the future will rely heavily on these sources to a much greater extent than today. For this research, prosumers are concerning consumers with solar panels as a distributed generation source. The reason for this limitation is due to the discourse concerning distributed generation in the household is mostly relating to solar panels.

Traditionally, electricity production has occurred at centralised power-plants. In Norway, this has mainly been hydro-plants due to the access to the natural resource (Olje- og energidepartementet, 2016). The electricity generation has been attached to the transmission network, with some exception where the production has been directly connected to own consumption. The change from a one-directional to a bi-directional flow of electricity in the distribution network increases the complexity of the distribution. Traditionally, electric power has been flowing from the distribution grid to the consumer, but generation now flows both ways (Johansson et al., 2018). The utilisation of solar power energy can lead to disturbances in the voltage level, which could potentially overload the connection point and networks components like electricity lines and transformers (Johansson et al., 2018). This instability in the system is much due to the variability of the supply as it is weather dependent (Naber et al., 2017).

Prosumers are considered a valuable part of the future electricity grid because of their flexibility potential. By being able to control the intake and output of electricity from distributed sources, it is possible to shift or decreased the peak hours of the outtake from the grid. Increased flexibility in both generation and production can lead to better reliability and efficiency in the distribution network. This flexibility is also believed to reduce transfer losses and improve the security of own supply (Ruggiero et al., 2015). Thus, the prosumers from solar panels are found to have considerable potential, not only due to its renewable character but also increased energy efficiency, flexibility and safety.

4.3.2 Demand tariffs

Demand tariffs are user-incentivised arrangements to either reduce consumption in short-term when the capacity is running low or long-run shifting of electricity loads (Annala et al., 2018). There are various approaches to demand tariffs which differs in their degree of mobility and complexity (Siano, 2014). Regardless of which of the demand tariff structures applied, the concept has been described as a crucial factor within the smart grid and refers to the "modifications in consumption in response to prices" (Greening, 2010, p. 1519). The consumers are encouraged to shift their electricity consumption patterns through price-incentives. Hence, through increased interaction and response by the consumers, it is possible to use the electricity produced more efficiently and beneficially for the grid (Siano, 2014).

The World Bank (2005) recognises six different patterns for behavioural change in the electricity market (see figure 5).

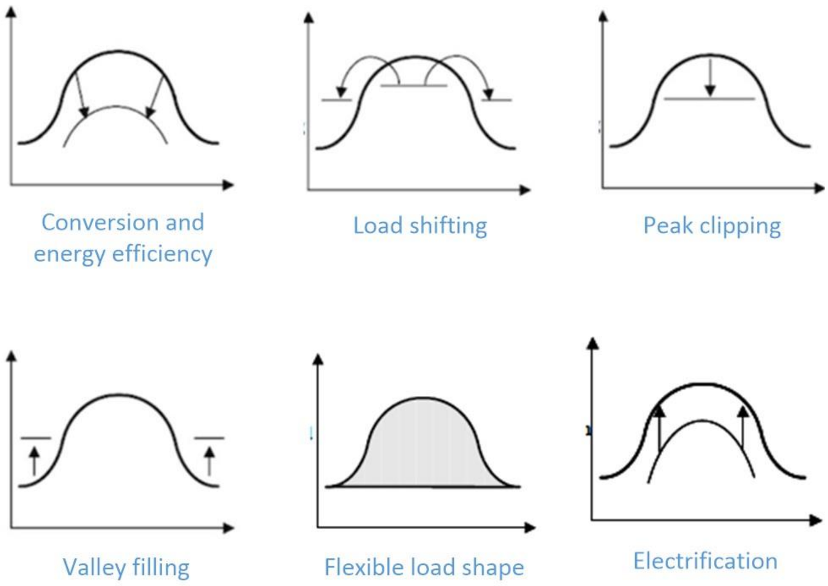

Figure 6 - *Load Shapes,* Retrieved from World Bank. 2005. *Primer on demand-side management with an emphasis on price-responsive programs (English).* Washington, DC: World Bank.

The various behavioural patterns have dissimilar impact on both the power outtake and total energy usage (see table 2). Except for electrification, the consumption changes are potentially beneficial for the electricity grid in avoiding or postponing grid investments. However, electrification is seen as an essential part of the sustainable transition towards renewable energy sources and is expected to increase especially as the transporting sector shifts energy consumption from fossil fuels towards renewable sources (Su, Eichi, Zeng, & Chow, 2012). The advantage of demand tariffs lies therefore in the adjustment in usage and the ability to offset the electrification by shifting or decreasing consumption away from hours with a high-efficiency power outtake of the grid. Changes in consumption can lead to several benefits for the electricity grid such as economic efficiency, enhanced reliability, relief of congestion and transmission constraints, reduced price volatility and potentially lower electricity prices (Greening, 2009).

Table 2 - *Consumption pattern changes*

Consumption pattern change	Description	Change in electricity consumption
Conversion and energy efficiency	Involve reducing consumption of electricity either by substituting with other energy sources, using more energy efficient equipment or reducing overall usage.	The overall usage goes down, and maximum outtake goes down.
Load shifting	Occurs when end user flattens out the consumption pattern by shifting electricity usage away from peak hours to hours of low usage.	The total consumption can be equal across the day but better utilised as maximum outtake goes down.
Peak clipping	The user reduces usage at the peak hours of the consumption pattern without shifting the consumption to other lower-usage hours.	The overall usage goes down, and maximum outtake goes down.
Valley filling	The use of electricity increases at hours of low total usage.	Overall consumption goes up, but not the maximum outtake.
Flexible load shape	The user is allowing the load to shape dynamically with grid conditions.	Uncertain.
Electrification	The user increases the overall demand for electricity and generally occurs due to substitution away from other energy sources.	Overall electricity use and maximum outtake go up.

Thus, there are potential benefits for both consumers and DSOs following changes in consumption from demand tariffs (Albadi & El-Saadany, 2008). The consumers can reduce their electricity bill, while the DSO could potentially avoid or defer infrastructure cost. The reputation of DSO is also expected to benefit as the grid tariff goes down and the electricity delivery is of higher quality (Nordic Council of Ministers, 2017). In addition to reduced cost and investment, the overall performance of the electricity grid is expected to operate more reliable and with increased safety. The retail electricity market is also likely to function better with greater product opportunities for customers and reduced price-volatility. However, these benefits are in large part dependent on reducing the network cost of investment and operation. Applying demand tariffs to the system without reducing the overall system cost would only lead to a redistribution of tariffs, benefiting some user at the expense of others (Nordic Council of Ministers, 2017).

The impact of demand tariffs is dependent on coordination among actors of the retail electricity system. This coordination is believed to be systematised through a price-signal that awards consumers when changing behaviour (Greening, 2009).

4.3.3 Battery storage

Battery storage refers to a form of consumer-based energy storage where electricity is able to be saved and consumed later. It is a form of There are other methods of energy storage, such as thermal, chemical, and mechanical (Zhao, Wu, Hu, Xu, & Rasmussen, 2015), which are not investigated in this study but provide similar capabilities.

The utilisation of battery storage in the grid has been seen as one of the key technologies for creating a reliable and sustainable electricity grid (Gladwin et al., 2016). It has been referred to as “The Holy Grail” for the industry (Dunn, Kamath, & Tarascon, 2011). Being able to store electricity from sustainable power sources from the excess output allows for greater distribution of electricity consumption and reduces the power outtake from the grid at peak demand hours (Teleke, Baran, Bhattacharya, & Huang, 2010). This flexibility in storage and usage allows for greater network efficiency and stability by reducing volatility in the grid (Gladwin et al., 2016).

4.3.4 Energy management systems

EMS are solutions intended to control and operate the usage of electricity in a beneficial way for the consumer and the grid. They are "characterised by automated operations concerning electricity and heat regulation that need little manual interference" (Wissner, 2011, p. 2514). Thus, automation is an important aspect of smarter electricity use in households and reflects the interconnectedness between many of the smart grid-innovations. A smart system without the integration of automatic response to prices or needs in the grid (demand tariffs) or demand-side management by DSOs, suppliers or third-party actors, would have low overall benefits for the grid.

EMS is closely related to the Internet of Things (IoT) which refers to an environment where "everyday things would support interoperability to achieve a common goal" (Gupta & Quamara, 2018, p. 1). Thus, concerning the electricity system, automated systems are often referred to as smart houses where appliances, such as water heaters, EV-chargers, dishwashers and laundry machines, are interconnected to achieve more optimal usage of the electricity.

5 Analysis and discussion

This chapter reflects on the diffusion of smart grid-innovations and the DSO position as a change agent regarding the three stages of knowledge, persuasion and implementation in the innovation-decision process. Further, the analysis draws upon alterations in the innovation system following a planned implementation of the supplier-centric market model. This change in the innovation system affects the communication link between the DSO and end user. It is, therefore, affecting the DSO as a change agent. Considering the contemporary dynamics of the retail electricity market, it is important to investigate these changes as the sector aspire to diffuse smart grid-innovations on a large scale. Finding appropriate measures to structure the innovation system according to these changes can bring greater efficiency, flexibility and sustainability into the system.

The chapter is divided into two sections. First, the individual smart grid-innovations in the study are briefly analysed and discussed by themselves in relation to the three stages of the diffusion process. This is significant information for the rest of the analysis as it highlights the reality of diffusion and demonstrates the current status of end user adoption, the importance of diffusion of the innovations, and the issues relating to the spread of the innovations. The latter part of the analysis looks at the position of the DSO as a change agent concerning the three stages of the innovation-decision process. For each stage the effects of the supplier-centric model are discussed and how the change in the structure of the innovation system has affected the role of the DSO. The analysis is based on interviews, sector reports and other relevant literature.

5.1 Diffusion of smart grid-innovations

The term smart grid is an umbrella concept containing several innovations, technologies, actors, organisations and institutions. While the idea of a smart grid is relatively unacknowledged among consumers (Gangale, Mengolini, & Onyeji, 2013), there may be differences among the innovations making up the smart grid. Hence, the next section looks at the four innovations examined within this thesis and issues related to the diffusion of the individual innovations.

The status of diffusion, the perception among the experts, and potential barriers for large-scale diffusion of each smart grid-innovation will have implications for the relevance of the innovation and the necessity to adjust the innovation system.

5.1.1 Prosumers

Prosumers and solar panels have been considered an important aspect of the smart grid and the future of the retail electricity market (Grijalva & Tariq, 2011). While the bi-directional flow of electricity increases the complexity of grid operation (Johansson et al., 2018), prosumers are mainly associated with greater user flexibility and considered a climate-friendly source (Grijalva & Tariq, 2011).

The DSO representatives interviewed regarded prosumers to be the smart grid-innovation with the greatest interest among end users, in particular, a heightened attentiveness to solar panels. This perception is consistent with reports on solar panels and prosumer interest (Multiconsult & Asplan Viak, 2018; WWF & Accenture, 2016). A sharp increase in media reports on the topic is also evident (see figure 6).

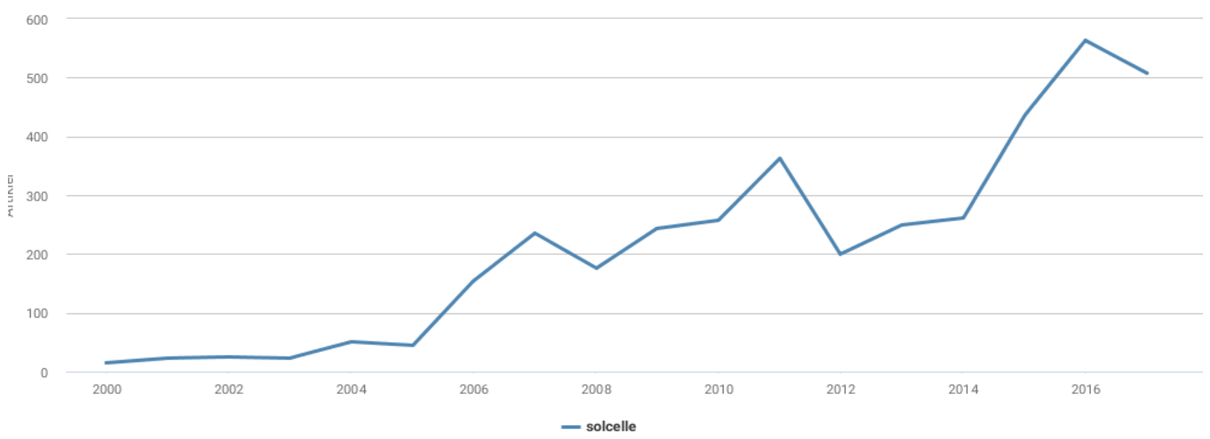

Figure 7 – *Development the number of Norwegian mass media articles containing the term solar panels ("solcelle" in Norwegian) from 1.1.2000 to 31.12.2017,* retrieved from Retriever Atekst 02.10.2018

However, the overall number of prosumers remains relatively low. “It has accelerated only recently”, said one respondent (DSO 4B), which reckons the percentage lies about 0,0004% of the overall customers. The relative meagre number of prosumers was reiterated by a second respondent (DSO 1) jokingly stating that “we have seen an increase in solar panels (prosumers)…last year the number of requests doubled from 1 to 2”. Another respondent (DSO 3) said the number was single digits, but that they had established a system to handle more requests in the future as they were expecting the number to increase. The interest for solar panels had also been increasing among larger industrial customers, where usage is typically higher and therefore the benefits potentially greater. As an example, Norway's largest solar panel structure is located on top of an industrial building[29]. Thus, there was a general agreement amongst the respondents that the number of prosumers was increasing and would also be growing in the future among all types of end user groups.

One respondent (DSO 2) suggested that the contemporary interest in solar panels correlated with subsidies from the government, which is consistent with the literature (Karakaya et al., 2015). Through ENOVA, a government-owned organisation working towards lowering emission from greenhouse-gases, it is possible to receive up to 28 750kr in instalment-subsidies on own energy production[30]. The environmental effect of this was questioned by another respondent (DSO 2) as almost all power generation in Norway is considered renewable. The beneficial political environment for prosumers could, therefore, account for some of the increased attention to solar panels.

In a report from 2014, consumer knowledge and few economic incentives were considered two of the most significant barriers for expansion of solar panels, while the implementation of the panels was considered less problematic (Multiconsult, 2014). Although the knowledge and incentives are improving, it has been argued that DSO differs in their ability to inform on the issue (Multiconsult & Asplan Viak, 2018). In particular, economic incentives, besides installation subsidies, is typically low or non-existent, so other motivations such as perceived environmental benefits and curiosity about new technologies are considered significant (WWF & Accenture, 2016). This can be accounted for by the relatively low electricity price, which reduces the potential savings or gains from being a prosumer. These findings were echoed in one interview (DSO 2), where prosumers were identified as having a particular interest in either technical systems or the environmental aspect. Additionally, at the smart grid conference of 2018, the CTO of the commercial enterprise behind Norway's largest solar panel structure explained how it was his technical background and interest that had instigated this interest in solar panels (Olsen, 2018).

[29] https://www.tu.no/artikler/na-er-norges-storste-solcelle-anlegg-blitt-nesten-tre-ganger-sa-stort/346914
[30] https://www.enova.no/privat/alle-energitiltak/solenergi/el-produksjon-/

5.1.2 Demand tariffs

The concept of demand tariffs is a process innovation within the smart grid concept with considerable expectations for shifting and reducing consumption (Faruqui & Sergici, 2010). NVE is currently in the process of evaluating demand tariffs in the Norwegian retail electricity market[31]. A suggestion from the regulator was sent out for consultation in November 2017 but received large scepticism from the industry actors[32]. A new proposition was sent out in the spring of 2017 with the intention to implement the first regulatory amendments by January 1st 2019 (NVE, 2017a).

Without the demand tariff scheme in place, it is difficult to evaluate the strength of the diffusion. There is, however, demand tariffs put in place in other sectors which can provide insights. Variable pricing has been introduced in the sporting industry, hotel industry and airline industry, but these sectors have experienced a slow diffusion of these innovations[33]. Further, there have been several pilot projects experimenting with demand tariffs, with varying results. A study done on changing electricity prices in Denmark showed that they had effects on dishwashing, laundering and EV charging (Friis & Haunstrup Christensen, 2016). These findings suggest that the economic incentives can have beneficial results but is not necessarily enough by themselves. The ability to understand the pricing scheme has been considered as an important aspect for the slow diffusion (Faruqui & Sergici, 2010). Getting the end users interested and educated about the possibilities with demand tariffs is therefore considered a key aspect for the smart grid.

Within Norway, some commercial buildings already have demand tariffs in place, but despite having a price-signal one regulator respondent (REG 1B) argues that many industrial companies do not take advantage of these. These experiences may suggest that there is a threshold for adaption of demand tariffs for consumers, either relating to price incentives or consumer comfort.

It was pointed out by one of the respondents (DSO 2) that especially household customers would get more incentives once the demand tariffs are put in place. However, one the

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[31] https://www.nve.no/om-nve/regelverk/forskriftsendringer-pa-horing/horing-forslag-til-endringer-i-forskrift-om-kontroll-av-nettvirksomhet-tariffer-avsluttet/

[32] https://www.energinorge.no/fagomrader/stromnett/nyheter/2018/nve-revurderer-nye-effekttariffer-etter-stor-motstanden/

[33] https://www.forbes.com/sites/prishe/2012/01/06/dynamic-pricing-the-future-of-ticket-pricing-in-sports/#3260f687600f

respondent categorised consumers as either active and interested in changing consumer behaviour, or passive. The latter would more likely be irritated with petitions to alter behavioural patterns. Hence, differences among end user are likely to influence the acceptance and usage of a new demand tariffs scheme.

5.1.3 Battery storage

Batteries have been considered a vital aspect of the smart grid as it can store and thereby shift electricity consumption over time. Storing of electricity is a radical change to the sector as electricity is traditionally considered an energy source that needs to be consumed simultaneously as production. Battery storage is therefore not only providing a flattening of the consumption curve, but it also makes rapid activation of electricity possible. One respondent (DSO 2) referred to it as "the missing link" due to its qualities for bringing flexibility into the system. The massive investments in battery production indicate that there is a growing need for this technology[34].

Currently, there are few batteries in the household for energy storage. For many industry actors, battery storage remains mostly at the pilot stage, but there are some solutions in the market, and the potential is regarded as high (Luo, Wang, Dooner, & Clarke, 2015). Specifically, the number of EV batteries are increasing rapidly and considered to be a potential energy source for the household (Sun, Lampe, & Wong, 2015). Additionally, there are a few third-party actors providing battery storage solutions. However, the cost of obtaining and installing these solutions are relatively grand compared to the expected savings[35]. Similarly, some larger industry customers have inserted batteries[36]. This suggests that there is a growing interest for batteries and high expectations within the sector for their capabilities.

Several arguments are explaining the slow diffusion of battery storage units. Cost incentives are regarded as the primary explanation (Roberts & Sandberg, 2011), where low electricity prices and high initial investment cost can diminish the interest for batteries in the household (Mulder et al., 2013). The Norwegian retail electricity market has a relatively low price compared to many other countries, which helps to explain the limited diffusion of batteries.

[34] https://energiogklima.no/nyhet/fem-paa-fredag/fem-pa-fredag-milliardsatsing-pa-batterier-i-eu/
[35] https://www.tu.no/artikler/norsk-selskap-lanserer-batteri-som-lar-deg-lagre-10-000-kilowattimer/394957
[36] http://www.odd.no/nyheter/skagerak-energilab

Similarly, there are no subsidies on the initial investments, such as there is with solar panels. Further, there have been safety concerns regarding having batteries in the household which could lead to the prohibition of certain battery types[37]

5.1.4 Energy management systems

EMS is closely related to demand tariffs as it allows for active participation by the user (Shafie-Khah & Siano, 2018). Notably, the ability to automate the response do changes in pricing has been seen as a key aspect of the smart grid as it allows for shifting of electricity consumption (Du & Lu, 2011). One respondent (IND 1) argued that EMS would make it both cheaper and more straightforward for the end user and that the market for these systems would increase rapidly as big international corporations such as Google, Amazon and Apple are entering the domestic market. The sales of Google Home support this assertion, as orders have increased significantly since it was announced it would feature a Norwegian voice assistant[38]. However, there is a difference between home automated systems and home energy management. While the home automated systems allow for control of electricity usage, it does not necessarily do so and is therefore not necessarily an EMS.

Overall diffusion of EMS is low[39]. Smart houses are reportedly accounting for only 2-3 per cent of current household and about five per cent of new buildings[40]. Thus, there is considerable potential for the implementation of these solutions. However, some systems are increasingly noticeable. One respondent (DSO 3) explained how they had a supplier who sold automated systems which would automatically charge when prices were at its lowest. Another respondent (DSO 1) pointed to small networks connecting EV charging and solar panels as the most prominent. According to one of the regulator representatives (REG 1A), it was typically automated systems for EV-charging and commercial buildings that have had an increase recently (REG 1A). This increase is relating to the maturity of the technology and the simplicity of implementation and use. Another regulator respondent (REG 1B) pointed to commercial buildings which already have demand tariffs, but despite having strong signals, they saw that many industrial companies do not take advantage of these. This lack of adoption

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[37] https://reneweconomy.com.au/lithium-ion-battery-storage-may-be-banned-inside-australian-homes-57002/
[38] https://www.tek.no/artikler/komplett-solgte-23-ganger-sa-mange-google-home-som-vanlig/448344
[39] https://brage.bibsys.no/xmlui/handle/11250/220856
[40] http://www.cw.no/artikkel/smarte-hjem/ti-ganger-flere-smarthus

is likely due to the absence of an integrated EMS, which makes the utilisation of demand tariffs strenuous.

While there is an increase in the supply of automated systems, it is unclear to what degree these can integrate into the electricity usage and influence consumer behaviour. However, it highlights the potential of EMS and the digitalisation of households. The representative from the industry association accentuated that the EMS would be increasingly popular as they would connect to other smart grid-applications. “Giving them (the customers) the total experience, that will be the future” (IND 1). This bundling of commodities was further exemplified by the combination of solar panels and EV-charging, where electricity usage could be distributed across the day and night, and the consumer would end up with a lower electricity bill.

Batteries together with EMS which are providing flexibility were believed to become a part of the electricity system soon by one of the regulator respondents (REG 1A). Similarly, automated systems which could utilise flexibility by temporarily disconnecting water heaters or other applications were likely to enter the market one respondent (DSO 3) explained. Thus, there are high expectations for the home energy management systems in the future with greater interconnectivity to applications and other smart grid features.

5.1.5 Summary

Figure 7 displays a summary of the smart grid-innovations in the innovations system. Prosumers and solar panels have been receiving increased attention over the last couple of years, and there has been a growth in the number of prosumers as of late. However, knowledge about the possibilities and cost-incentives are regarded as barriers in today’s market. The cost-incentives are often related to the relatively low price of electricity in Norway.

Table 3 - *Status and barriers for smart grid-innovations*

Innovation	Status	Barriers for diffusion
Prosumers	Early-adopters, growing	Knowledge, incentives
Demand tariffs	Missing, except for industry actors	Regulation, knowledge, incentives
Battery storage	Low diffusion, growing	Incentives
Energy management systems	Low diffusion, growing	Incentives, Implementation

Demand tariffs are not existing in the retail electricity market except for industrial actors. However, there are expectations about the incentives this will give for changes in consumption especially as they are connected to other smart grid-applications such as home management systems. Regulation is expected to be put in place by the start of 2019.

Battery storage has been considered a key aspect for the future of the electricity grid and huge investments are made in batteries for home storage of electricity. At the moment there are mainly pilot projects with batteries and the overall diffusion is low, mostly due to the immaturity of the technology and the cost of the products.

Home energy management systems are increasingly popular. As of now, it is generally systems which control EV charging which is experiencing diffusion, but other systems which have the potential to manage electricity usage, such as Google Home, are increasingly sold. The possibility of these systems is significant as they can interconnect with other smart grid-applications.

5.2 DSO as a change agent in the retail electricity market

The end users have been recognised as a significant actor for the implementation of the smart grid (Geert P.J. Verbong, Beemsterboer, & Sengers, 2013). A change agent has an influential role towards the end user in an innovation system. Thus, affecting the end user at the stages of knowledge, persuasion and implementation is increasingly important. The position of the change agent could both be favourable and unfavourable towards diffusion depending on the stance of the change agent on the innovation. Further, the change agent often possesses expertise within the area and is regarded relevant for policy development and interactions within the innovation system.

The DSO correspond well with the role of a change agent in the retail electricity market due to their central position in the sector. The following sections are divided into the three stages of the innovation-decision process where interaction between a change agent and the end user occur: knowledge, persuasion and implementation. Each section is used to evaluate and assess the strength of the DSO as a change agent for the diffusion of smart grid-innovations.

5.2.1 Knowledge

Educating and enlightening consumers about smart grid-innovations have been considered a key aspect in the transition towards a smarter grid (Gangale, Mengolini, & Onyeji, 2013). Within the smart grid, the end user is changing from a passive receiver of electricity to an active part of the electricity grid system (Goulden, Bedwell, Rennick-Egglestone, Rodden, & Spence, 2014). Greater consumer awareness of own behavioural pattern is therefore needed to be able to change or reduce consumption and provide user-flexibility in the market. Among the respondents, it was confirmed that the smart grid could bring significant benefits for the consumer if there were active participation and control of own consumption. Still, the awareness of the smart grid remains low[41]. Knowledge about the functionality and potential of the smart grid needs to be dispersed to consumers. This knowledge-dispersion was considered a difficult but important challenge. As one respondent (DSO 3) put it: “The customers know less about electricity than almost anything within infrastructure in society…the power is just there, and the customer regards it as a given that it arrives”. The DSO respondents were therefore resolute that their role towards the end user was essential to assist and allow for greater consumer participation in the market.

According to the respondents, the DSO has traditionally had an active role towards the consumers, being a natural contact point for grid tariffs and other grid-related issues. However, over the last century, there had only been moderate changes to the electricity grid with little need for further interaction between the actors. With the influx of smart grid-innovations, there has been a heightened need for interaction as these innovations brings more complexity into the system. Several aspects were brought up by the DSO respondents when asked about why customer contact was seen as an important aspect of the DSO operation. Safety and preparedness, investments, the operation of the grid, information and counselling were all brought up as becoming more relevant recently.

Especially the changing end user and the diversification of user groups was considered more relevant in recent years. One DSO respondent (DSO 2) explained the need to have a better overview of the different types of customers, knowing which type of consumer they were. As an example, customers with EVs and EV-charging was brought up as a relevant characteristic for the DSO to understand, as these users affect the grid-operation differently than traditional

[41] https://www.power-technology.com/features/featuresmart-grids-the-consumer-perspective-5784886/

users. Further, they could potentially provide user-flexibility and more reliability to the grid if informed about their implications for the grid.

There are differences in the proactiveness in the retail electricity market among the consumers. According to a survey done by the Smart Energy Consumer Collaborative (2018) consumers can be grouped into three levels of engagement: always engaged, selectively engaged and rarely engaged[42]. The selectively engaged consumer group is regarded as an important target group for the diffusion of smart grid-innovations as they are potentially interested in solutions that may reduce their utility cost and improve the efficiency of electricity usage[43]. In addition to varying interest in the smart grid, other characteristics of the end user differ. Consumers can be divided into commercial and household users. While household users are larger in numbers, industrial customers often require higher power output for the production of commodities and materials. The differences in characteristics have implications for how the customer contact can be strengthened. Although the customers were generally considered more complex recently, it was highlighted by one respondent (IND 1) that the knowledge-barrier probably would decrease in the future as younger users will be more accustomed to the technological solutions of the smart grid. Having a better overview of the characteristics of the end user is relevant as it enables the DSO to target selectively engaged consumers. Utilising resources to inform and educate the most likely adopters, together with an influx of younger consumers, could increase the overall knowledge among consumers about the smart grid.

Despite a general agreement that there was a need for greater knowledge among the end users, the responsibility for this was somewhat uncertain. Knowledge about smart grid-innovations contains both a commercial aspect, as many of the technologies are sold as commodities, and an operational aspect. Thus, both DSOs, power suppliers and third-party actors are arguably relevant for the education of the end user on these innovations. When asked about informing the consumers about the potential benefits of the smart grid, one respondent (DSO 4B) asked for greater involvement by NVE, especially when regulations are involved. The following statement can illustrate this sentiment: “it is certain that NVE should inform and market the benefits from what they have imposed on the sector”. However, the respondent also reflected on the DSO role, claiming that their role was valuable for informing about future developments in the sector. Another respondent (DSO 3) echoed this attitude stating that the

[42] https://smartenergycc.org/2018-state-of-the-consumer-report/
[43] https://smartenergycc.org/2018-state-of-the-consumer-report/

DSO “need to be ahead and understand the customer better…humbler over the fact that the customer may have other expectations and demands from us the previous”. This uncertainty about responsibility can function as a barrier for knowledge-dispersion as it weakens the consistency of information. The type and amount of information could then be dependent on the local DSO or power suppliers in the area, rather than a universal dispersion of knowledge. Further, third-party actors could potentially sell products that need to be integrated into the electricity grid, without the awareness of the DSOs.

For two of the respondents (DSO 2; DSO 3) customer contact was not necessarily a requirement, but rather but rather an expectation among the customers that they would be able to inform them. Further, one of the respondents (DSO 3) explained:

“We have a massive task in educating the customers about the future and energy…we have to educate the customer on how to use the electricity most reasonable to get a good system.”

The responsibility for informing and educating the consumer can also be dependent on the innovation. One respondent (DSO 3) saw it as their responsibility to inform as long as the issue was related to the grid, such as new tariffs and how to utilise the potential for flexibility. Other areas were more likely to belong to third-parties or power suppliers. Further, this information needed to be diffused early, so that customers could react to it. As the respondent put it: “you cannot just introduce demand tariffs and inform (the customer) about it, and then the customer is supposed to find solutions on their own, that doesn’t work”.

The role of integrated companies was brought up in several of the interviews, and many respondents argued that the knowledge dispersion between DSOs and power suppliers would be simpler within an integrated company. Notably, the close connection between supplier and DSO in an integrated company could provide benefits for both actors. One integrated DSO explained that their customer service would have an easier job of attaining competence on matters such as grid-tariffs. The respondent (DSO 4B) informed that they “have had a joint customer service centre in the company, so they have a culture of helping any inquiries from customers, such as grid-tariff, despite being a power supplier”. One CEO (DSO 3) explained how an integrated company with customer service being handle jointly had a great value for them, especially as a smaller company because they were better equipped to handle any issue. In this particular integrated company, it was the supplier side of the company which dealt with advice and recommendations for prosumers. Another DSO respondent (DSO 4A) highlighted how their integrated power supplier ran an ad for distributed (solar) generation.

Thus, the advisory role of the change agent in an integrated company is easier resolved than a single-standing actor, since the potential benefits for the grid are more accessible to communicate internally than towards other actors within the system. Further, the customer contact with larger industrial actors, who often affect the grid more prominently than household actors, was also considered easier in an integrated company, says one respondent (DSO 1). Further, one respondent (DSO 2) explained that cooperation would need to be increased in areas with more suppliers as well, which often are more complicated due to the many actors within the market.

The need for urgency in knowledge dispersion was evident among several respondents. One respondent said it was difficult to know whether there were coming third-party actors into the market who would push out information to the consumers, or if they had to do it themselves. One respondent (DSO 2) said that one possibility was to cooperate with third-parties and initiate them to take part in the information-pushing. The potential and expectation for cooperation are therefore seen as a critical element in the future electricity grid. With a multitude of actors benefiting from resolving the slow diffusion of smart grid-innovation, it is relevant to avoid uncertainties among the actors about responsibilities. Instead, greater cooperation can be advantageous for several actors within the market. The diffusion of smart grid-innovations can, therefore, be seen as a joint venture within the sector.

Effects of the supplier-centric model

The effects of the supplier-centric model are significant at the knowledge stage, as most of the customer contact will be shifted towards the power suppliers. There were strong sentiments about the prosperity of this, based on the perceived strong position of the DSO when it comes to knowledge dispersion. In particular, the actuality in diminishing the communication with consumers was considered an issue as the power supplier is regarded as the natural contact point for the end users within the new model. One respondent (DSO 2) viewed the reduced connection to consumers problematic as providing electricity was considered a service which needed a communication channel towards the customers (DSO 2). The general perception of the DSO respondents was that they regarded their job more difficult without a strong connection to the customers, hence a weakening of their position as a change agent.

Among the DSOs there is a strong linkage between information, billing and customer contact. The supplier-centric model affects the customer contact both in a practical sense and a symbolic sense. Previously, communication has typically been preserved through information sent out alongside the bill, and the billing scheme has been regarded as the primary communication channel towards the customers. This loss of a communication channel was brought up by a second DSO respondent (DSO 3) which explained that “as soon as the DSO is no longer responsible for the billing…you lose the customer contact”. Further, a second respondent (DSO 2) explained that with the supplier-centric model it is not only information sent out from DSO which is disturbing the communication with end users, but also the natural contact point for the consumers become the power suppliers rather than the DSOs.

For many respondents, customer contact through billing was regarded as diminished or outdated already. Hence, the knowledge stage of the diffusion-process was perceived to be weakened even before an eventual implementation of the supplier-centric market model. The reduced communication opportunities with the customers had increasingly been an issue, much due to the new dynamics of the electric sector with the introduction of smart grid-innovations. One DSO respondent (DSO 3) maintained that there had to be a direct link to the customer regardless of whether it is to inform about tariffs or blackouts in the area. Thus, there is a need for a strong relationship between end users and DSOs irrespective of the market model. The supplier-centric model would, however, accelerate the urgency to adapt. Greater interactivity with the customers was seen as a key part in maintaining a strong communication link to the end users, becoming more proactive. As one respondent (DSO 2) stated:

“(As a customer) I need to talk to the DSO about what to do. Which solution should I choose? Can I become a flexible customer? Can I make money on it? This is stuff that only the DSO is competent to answer”.

To be proactive in the relationship with end users, many of the DSO have begun to look at other communication channels for reaching the consumers. App-solutions, text-messaging, e-mails, Facebook and customer-portals at the website were brought up as possible channels. One respondent (DSO 3) explained the need to improve on digital platforms, utilising technologies that are associated with a younger audience, such as Snapchat and Facebook. Mobile communication was regarded as the most important channel for communication going forward, whether through text-messaging, apps or website.

One respondent (DSO 2) explained how they had begun to approach customers in an even more proactive way:

"We are looking at going out to the customer and talk to them, which we have never done before…now we have own teams talking to construction entrepreneurs, housing cooperatives, EV actors…to see what they are concerned about, but also information we wish they should have".

Further, getting in dialogue with customers with high consumption, such as industrial customers can be increasingly important as these are end users who affect the grid to a greater extent. The economic consequences for both actors could in these cases be vast, making the environment for cooperation and dialogue better.

It is clear that the supplier-centric model reduces the linkage between DSOs and customers, thus reducing the effectiveness of the DSO as a change agent. However, this is not necessarily defective for the innovation-decision process, as other change agents might take more responsibility at this stage. One regulator respondent (REG 1A) believed this would be the responsibility of power suppliers or other third-party actors, claiming that competition in the market would resolve issues relating to the spread of information and knowledge. Thus, an implementation of the supplier-centric model reduces the uncertainty about responsibility.

While the DSOs regarded their weakened position as a concern, the representative from the industry association (IND 1) and the regulator representatives (REG 1A; REG 1B) found this to be positive for the retail electricity market. The industry representative (IND 1) agreed that the DSOs would become invisible towards the customers but maintained that this would be favourable for the DSOs as they could focus on grid-operations. This reduced visibility in the market is in line with the view of the regulator who wishes to encourage the DSO as grid-operators rather than involving them in what is considered commercial activity. "Much of what we work with have a goal of creating more efficient and cultivated DSO which is focusing on grid-operations, and no other concerns" (REG 1A). Further, the respondent saw it as beneficial that the DSO does not have to concern themselves with customer service relating to tariffs and pricing. Further, it was argued that the supplier-centric model makes customer service a competitive aspect among the power suppliers. Thus, improving the ability to inform about smart grid-innovations and diffuse these would be a commercial asset for the power suppliers and other third-party actors. One respondent (IND 1) explained the commerciality of customer service with the following statement: “It is not just about delivering a low price, it is much more” (IND 1).

5.2.2 Persuasion

At the persuasion stage, the end user develops an attitude towards the innovation, either favourable or unfavourable (Rogers, 2003). Thus, given sufficient knowledge about the innovation, the end user forms an opinion about whether the innovation is something to pursue. This evaluation is often related to the incentives for an end user to adopt an innovation. Further, incentives for the end user can be associated with incentives for other actors or change agents. According to the DOI theory, a change agent can both impact the innovation process positively and negative, and the direction often depends on the change agent’s perception of the innovation (Rogers, 2003). Thus, as an addition to end user incentives, the persuasion can often rely on the change agents own incentives for user-adoption. The persuasion stage of the innovation-decision process is also connected to the reputation, trustworthiness, and appearance of the change agent.

There are generally three motivations for adoption of smart grid-innovations. First, the economic benefits for the end users are the most important driver for a transition towards utilisation of smart grid-innovations (Karakaya et al., 2015). Second, the climate was brought up in the interviews as an incentive for one group of end users, if the utilisation of the new technology is perceived as an environmentally friendly. Third, technological curiosity was also brought up as a motivation for the adoption of smart grid-innovations.

The economic efficiency of the whole retail electricity market was brought up as an incentive for the DSOs to diffuse smart grid-innovations. “As a DSO we are obligated to think socio-economically. I believe it would be a principle mistake if the DSO shouldn’t be able if it is a reasonable measure”, said one respondent (DSO 1). It was argued that the same socio-economic incentive was not apparent among the power suppliers, which was less likely to pursue the role of a motivator for the end user unless they were obligated to do so. Thus, DSOs have an incentive to bring flexibility and efficiency into the retail electricity market, which is associated with lower expenses, better reliability and security.

The change agent’s reputation and perception among the end user are important for the diffusion of innovations. One DSO (DSO 2) underlined that it was becoming increasingly important for them to keep the grid-tariff as low as possible to avoid unsatisfied customers. The apparent diligence in preserving a reputation might seem strange for a monopolistic actor, but the respondent urged that they have a societal motivation. As long as they were having a relationship with customers, it was deemed necessary to maintain a good reputation.

One respondent (IND 1) indicated that the end users would be more interested in the smart grid-innovations and finding solutions that would be beneficial for them, hence increasing the number of proactive users. This self-interest in the smart grid-innovations would reduce the overall need for a change agent to diffuse the innovations as the demand rises independently. It was pointed out that the price-signal is an effective motivator for the end user to find these solutions. The price-signal has been brought up in several interviews as the most crucial factor for incentivising users to endorse the smart grid-innovations. Sending the right price-signal is essential for the functioning of the market (Cramton, 2017). One of the concerns for the respondents was that the price-signal would be concealed in the hands of the power suppliers' billing scheme. The degree to which this was a problem was differing among the respondents. All respondents agreed that the ability to diffuse the price-signal was related to the power suppliers' incentives. One respondent (DSO 4B) explained that "if they (the power supplier) get incentives to be a good informant for their customers, as a competitive advantage, then I think it will be a success". This increased competition among power suppliers is in line with the regulators wish for the supplier-centric model. Much of the motivation for the change of market model is to make customer relation a commercial asset, explained one regulator respondent (REG 1B).

Currently, there was general agreement that there was a lack of incentives within the whole market, due to the absence of demand tariffs. The implementation cost associated with many of the technologies were seen as a barrier, making them less likely to be beneficial for the consumers over a short term. Further, when it comes to realising a flexibility market, the need for significant price differences was indicated as a central factor for the future retail electricity market. However, one respondent stressed the importance of being ahead of the customers and educate them in advance to achieve economic benefits within the electricity system once the demand tariffs are implemented (DSO 1). Thus, there is a linkage between the two stages of knowledge and persuasion.

Effects of the supplier-centric model

The persuasion stage reflects on the incentives and motivation for end users to adopt the innovations. Within the retail electricity market persuasion is closely related to the cost encouragements for end users. Much of the discussion regarding incentives and the supplier-centric model was therefore centred around the price-signal and whether this would be reflected in a combined bill and which actors had incentives for promoting these end user incentives.

One respondent (DSO 1) maintained that with a supplier-centric model all information and incentives relating to the smart grid-innovations is the responsibility of the power supplier. This responsibility has been a central part of the reasoning for the switch to a supplier-centric model, considering the monopolistic nature of the DSOs. Without the risk of losing any customers, economic theory maintains that these actors have fewer incentives to focus and use resources on customers. The representatives from the regulator (REG 1A; REG 1B) reiterated this market mechanism, pointing out that being a monopolistic actor does not require the organisation to satisfy the customers to keep them. However, several of the DSO pointed out that despite being a monopolistic actor, they were concerned about their reputation. "All organisations which have customers need to be concerned about their customers…for us it is important to have customers that are as satisfied as possible" said one respondent (DSO 4A). In addition, one respondent (DSO 3) explained the concern for becoming a closed organisation with less customer contact. "Then you have to be really aware of not becoming a, in negative terms, monopolist". The representative compared their organisation to that of *Vinmonopolet*, another monopolist actor in Norway, which is both experts within their field, but also customer-centred.

Further, it was pointed out that the incentive for the power supplier to persuade the customers to adopt innovations was not necessarily apparent, arguing that the primary motivation for power suppliers is to have the user use more rather than less electricity. The respondent elaborated that the supplier would have to adapt and focus more on service, rather than counting kilowatts (DSO 1).

This issue was argued to be resolved by market mechanisms by the regulator respondents, as power suppliers would have greater incentives for bringing incentives to the customers. They would benefit through better customer service, which would be a competitive arena for suppliers in the new model. Thus, incentives for the consumers would be incentives for the suppliers to compete for, said one regulator respondent (REG 1A). The harmonising of incentives among the actors was perceived as the role of NVE, as they set the rules of the game, especially on how the framework for new tariffs would work. This would determine how the price-signal would be distributed. In the interview with the regulators, the respondents (REG 1A; REG 1B) explained that there is a goal to make the tariffs more reflective of efficiency outtake and capacity rather than energy usage. However, one respondent (REG 1B) pointed out that the incentives should not be too strong either. “Yes, there are some savings by reducing customer consumption, but it should not bother the customers more than necessary…the goal is not to change consumption as much as possible”.

As soon as there are incentives for the consumers, the suppliers would take an economic risk in not responding to these incentives, it was argued by one respondent (REG 1A).

“The ones with the best solutions and lowest prices, those are the ones that win the competition. At least in theory. So, they have to compete for customers, which gives greater incentives to develop good information systems and good automated systems which the customer can use to cut consumption and get a lower electricity bill”.

A DSO respondent (DSO 2) agreed that customers who would have sufficient to save on electricity would be interested in the innovations. However, it was argued that this required informing and advising the consumers about cost-efficient measures in advice, and this was not reflected in the market at the moment.

5.2.3 Implementation

Implementation relates to the actual application of the innovations. While the DSO will have to have a role to play in this context, due to their position as the operator for the distribution level grid, it is unclear to what degree. At a bare minimum, they are involved in grid-connectivity for all technologies and the operation of the grid will be affected by greater quantities of the smart grid-innovations such as batteries, as well as the introduction of demand tariffs and EMS. Further, it is generally recognised by all respondents that most of the smart grid-solutions will not be provided by the DSOs and that the actual smart grid-solutions will most likely be offered by third-parties and power suppliers. However, implementation is closely related to competence, which is a key characteristic of the DSO.

There was a general recognition among the interviewees that the DSO has the greatest competence about the grid and issues related to the management and operation. One respondent (DSO 3) reflected on the smart grid bringing more complexity to the grid and the need to be involved and updated on these changes. Thus, the role of the DSO concerning the implementation of the innovations is apparent, but a passive one. The DSO role will be operating in the background, not close towards the end user.

A passive role in the implementation of the smart grid-innovations would require a transfer of competence to other actors. One respondent (IND 1) argued that the competence within the DSOs needs to be decreased and shifted over to the power suppliers and other third-party actors. Transferring this competence over to other actors were seen as a likely solution by the respondents regarding their organisational affiliation. Thus, making the role of the DSO more advisory was again brought up as a probability. A transferring of competence would also mean a strengthening of the other actors as change agents in the innovation system.

The stage of implementation was considered an essential part of the diffusion of the smart grid-innovations. For one DSO representative, there was a difference between merely facilitating for new technology in the grid and facilitating so that the consumer uses the technology. “We have a couple of projects on how to best facilitate (new technologies), but we need to correspond more with the customers” (DSO 2). This processual feature of the smart grid-innovations illustrates how all three stages of knowledge, persuasion and implementation is closely related, highlighting the complexity of both the innovation system and the role of the change agent.

Among the DSOs there is increasing attention to innovative efforts, both on grid-operation and customer application of smart grid-innovations. There is a relatively broad focus on innovation projects. One regulator respondent (REG 1B) pointed out that the role of the DSO was to facilitate the customers, regardless of what solution the customer wanted. This understanding of their position is illustrated by the following statement:

> “if a customer asks for either more output, or to charge the EV quickly, or they are having a large solar-panel constructed, then it is isolated a challenge for the grid. Then it could have to strengthen (the grid). But, that is the DSO responsibility”.

The responsibility of grid connection may explain the relative wide focus DSOs has when it comes to innovation projects. With additional smart grid-innovations coming into the retail electricity market, the complexity of the user and connectivity issues rises. Of the interviewed DSOs, the two large-sized DSO has own research or innovation departments. All the respondents were utilising the NVE innovation scheme. One of the respondents (DSO 1) for a smaller DSO in the study expected to increase the innovative efforts in the future due to the new dynamics of the sector. This intensifying focus on innovation was also the case for the second of the smaller DSO according to the CEO respondent (DSO 3).

The motivation for undertaking innovation projects that are believed to be commercial services is explained with a need to understand and learn about the future of the grid. "As a DSO we are primarily motivated by finding solutions," said one respondent (DSO 3). This argument is evident by the several innovation projects relating to the smart grid conducted by DSOs. One respondent (DSO 1) had projects related to prosumers both in households and for industry and a pilot project for automated control of heating sources in the household. Another respondent (DSO 2) explained about a rapid increase in the size of their innovation department, looking especially at grid-operation and how to get the customer more flexible. "It is much more customer centred that in recent years…a lot of the projects looks at digitalising and customer contact".

Despite being pointed out as the most competent on grid-related issues, several DSOs were determined to improve their competence further. This expansion of their competence was seen as relevant regardless of their position within the retail electricity market because they were likely to be a buyer and user of some of the innovations in the sector. In particular, knowledge about innovations and technologies that could bring flexibility was seen as a vital resource in the future. One respondent (DSO 1) summarised their view regarding smart grid-innovations and knowledge as follow: "We need to know the customers and how it (smart grid-innovations) functions…and we need to orientate ourselves in the market". Thus, regardless of their future role in the retail electricity market, the DSOs are maintained on improving competence within the smart grid area.

Innovation projects were also seen as a possibility for DSO to display the commercial potential of innovations, which could later be adapted by third-parties or power suppliers. One regulator respondent (REG 1B) reflected on the dilemma of risky innovations in the electricity system: "It is an issue that commercial actors wish to wait for (innovations) to be economically beneficial, while DSO wants to test it out before it is too late" (REG 1B). An excellent example of an innovation that has displayed financial capabilities through a DSO innovation project is the NODES flexibility market. NODES is an innovation project conducted by the integrated company Agder Energi and Nord Pool, which has exhibited a practical application of a user-flexibility market. At the SmartGrid conference 2018 CEO of Nodes, Rune Hogga, discussed the issue surrounding commercial aspects for a monopolistic actor. Hogga explained that Agder Energi was prepared to sell out if it were considered a commercial activity for the DSO and regulation would prohibit them (Q&A, Rune Hogga, Smartgrid konferansen 2018, own notes). Thus, the role of NVE as a facilitator for the rules of the game was considered necessary for these types of activities.

The role of integrated companies was brought up as a dilemma relating to competence. It was understood as an easier task to transfer competence with integrated companies, where you could cooperate with the internal power supplier. However, the regulator respondents (REG 1A; REG 1B) pointed to the potentially problematic situations that may arise in integrated companies about the commercial aspects of the innovations. As one of the respondents (REG 1A) stated:

"Often owners of DSO have an ownership interest in companies that provide automated systems, which provide electricity, then they have to be really careful not to be in a situation where they are not providing the best solution to the customer, but the internal solution".

This area is, and will be, difficult to follow up in the future according to the second regulator respondent (REG 1B) and would potentially lead to a situation where the DSO is not allowed to give concrete advice on solutions. At the same time, the balance between including the DSO competence in these aspects was also pointed out by the regulator respondents, illustrated by this statement:

"The fact that the DSO sits on incredibly important competence, which is important that they share. At the same time, it is difficult to know to what degree they give an advantage to integrated affairs" (REG 1A).

Effects of the supplier-centric model

The effects of the supplier-centric market model on the implementation stage are limited, much due to the DSO role as a facilitator for new connections, and therefore new technologies and processes which are relating to the grid. At this stage, the DSO is obligated to provide the necessary service once the decision to adopt innovations are taken. This mechanism is in practice today, especially evident with prosumers who are connected and will not be affected by the supplier-centric market model.

The only issue brought up with the supplier-centric market model at the implementation stage was the gap in competence between DSO and other actors. Mainly, the issue related to the planned demand tariffs was a concern for one respondent (DSO 1) as the power suppliers would not have the ability to recognise challenges for the grid. "It will be interesting…the power supplier has about as much knowledge about power complications as the customer itself…but it is possible to learn, so it will be a process for the supplier to learn what efficiency output really is". One regulator respondent (REG 1A) argued that the power suppliers would have to increase the competence to be competitive.

Thus, it is expected that the DSO's competence about the grid needs to be transferred to power suppliers and other third-party actors within the retail electricity market regardless of the market model. As one respondent (IND 1) put it: "The power supplier needs to increase their customer contact…especially when it comes to technical competence and tariffs". This argument was approved among the DSOs, but one respondent (DSO 2) questioned the efficiency of transferring this competence to a third-party, instead of merely doing it themselves. Once again, it was generally recognised that this would be easier for integrated companies where employees could just be moved internally.

5.2.4 Summary

This research has been conducted to best answer the research question:

How does the supplier-centric model affect the role of DSOs as a change agent for the diffusion of smart grid-innovations?

To achieve this task, it has been necessary to divide the analysis into two sections. First, understanding the current status of the smart grid-innovations have been crucial to assess whether there is an issue with diffusion, and if so, what the barriers are. Second, it has been vital to understand the position of the DSO as a change agent and how strong this position is at the knowledge-, persuasion-, and implementation-stages of the innovation-decision process. Further, considering the position of the DSO as a change agent, the second section has also analysed and discussed the expected impacts of the supplier-centric model. Included in the findings are some potential measures to adapt the DSO role within the future retail electricity market.

A change agent is an actor within the system which holds a position of advocacy, information and implementation support (Dearing, 2009). The DSO maintains a central role in the retail electricity market also following the implementation of a supplier-centric model. The DSO will remain relevant for the diffusion of smart grid-innovations due to their operational and managerial role in the electricity grid at the distribution level. Customer contact will remain valuable for the DSO as they have incentives to act as a motivator for the diffusion of these innovations. The DSO functions as a government-affiliated intermediary and, therefore, has a greater societal perspective and responsibility than commercial actors. Considering the sustainable and efficient characteristics of the smart grid-innovations, this can be a valuable aspect to consider in the assessment of the innovation system as the DSO functions as a driver for adoption beyond economic gains.

The centrality of the DSO role is reflected within the research as the DSO has a relation to the end user at all stages of the innovation-decision process. A summary of the DSO role as a change agent in relation to the innovation-decision stages can be found in table 4, alongside the expected effects of the supplier-centric model and potential actions for the DSO to adapt to these changes.

Table 4 - *DSO as a change agent and the effects of the supplier-centric model*

Innovation-decision stage	DSO as a change agent	Effects of the supplier-centric model	Possible future actions for the DSO
Knowledge	Strong, but uncertainty about responsibilities	Weakened due to a reduced communication link	Create new communication channels Greater cooperation Advisory role for end users
Persuasion	Strong incentives to reduce or postpone investments through greater flexibility and efficiency	Uncertain, depends on the ability to transmit price-signals	Advisory role for other actors in the innovation system Transfer of incentives to other actors
Implementation	Strong, responsible for the grid-connectivity and operation	Strong, but limited	Increase innovation Transfer of competence to other actors

First, the DSO has traditionally had an active role in informing consumers about the electricity grid through their billing scheme. Information has been sent out alongside the billing and customer service have been a core instrument among the DSOs. However, with the introduction of smart grid-innovations, the responsibilities of the DSO have become unclear. Other actors within the retail electricity markets, such as power suppliers and third-party actors are expected to handle more of the information flow relating to these innovations. At the same time, there is a strong desire among the DSOs to maintain the customer-relationship with end user. This link will be weakened following an eventual implementation of the supplier-centric market model.

This research finds that the role of the DSO remains relevant as a change agent at the stage of knowledge. Thus, there is a need to maintain and improve the communication link with end users. Failing to construct such a linkage can result in a system weakness and requires a re-alignment of the system actors interests (Musiolik & Markard, 2011). Improving the direct link to end users is within the DSO interest and can be done in a proactive way, adapting the role of an advisor for the customers with regards to smart grid-innovations. It can also be in the interest of the end user to maintain a relationship to the DSO. The DSOs have valuable insights into decisions surrounding new constructions and connections to the grid, which has potential benefits for both actors. Further, there is a need for greater cooperation among the actors within the innovation system. The need to raise awareness about the smart grid is apparent, and there is significant societal potential if done sufficiently.

Second, the DSO has strong incentives for a large-scale application of smart grid-innovations as this has the potential to sharply reduce operation and investment cost related to grid maintenance and expansion. The incentives for DSO and end users are therefore strongly coinciding which makes their relationship concerning the diffusion of innovation strong. With the implementation of the supplier-centric model, the incentives will remain the same, but the dispersion of these incentives may be diminished. The reduced incentives relate to the combined billing scheme, which is potentially hiding the price-signal from reductions in grid-tariffs. However, if the regulator finds appropriate measures to guarantee that this price-signal will remain strong within the billing scheme this is less likely to be an issue. Similarly, if power supplier is finding own incentives to elucidate the price-signal the market may resolve this issue. Thus, greater cooperation among the actors is once again seen as beneficial.

Third, the DSO role in implementing smart grid-innovations will remain strong regardless of the market model. This position in the system is due to the nature of the DSO in operating the grid, which requires awareness of the implementation of smart grid-innovations and often the physical connection of the smart grid technologies. The uncertainties surrounding the supplier-centric model is, therefore, the degree of activity on behalf of the DSO. That the DSO will not be involved in any commercial activities is understood among all respondents. However, to avoid any uncertainties, regulation needs to be clear on this matter. Instead, the DSO can assist and advise other actors when it comes to competence about the grid. Thus, continued innovative efforts are relevant to remain competent, regardless of their weakened position towards the end users. This competency should be used to understand the smart grid and its potential and consequences. To best utilise the competence within the system some will need to be transferred over to the other actors within the system.

Lastly, a greater understanding of user groups has been relevant for the diffusion of smart grid-innovations. Understanding differences among customers are increasingly important as they are getting more diverse and complex. Further, the role of integrated companies was brought up as convenient with regards to the three stages of innovation-decision, as it makes the advisory role of the DSO less demanding as well as the transferring of competence and incentives more accessible. However, this is against the general advice of the regulator, which pursue less integration within the sector. Thus, finding a regulatory environment where the smart grid-innovations can diffuse and adopt is of utmost importance.

6 Conclusion

The retail electricity market is currently undergoing radical changes. Increased attention to environmental concerns has led to a rapid development of electrification in the transporting sector, and new trends are showing increased consumption and more complex usage of electricity. The smart grid has been regarded as the solution to these challenges, but the innovations within the smart grid concept are experiencing a slow diffusion into society. Using a SI perspective, this thesis has viewed the retail electricity market as an innovation system. In particular, the role of the DSO has been investigated as NVE are planning to implement a supplier-centric model in the Norwegian retail electricity market. This would lead to a disruption in the link between the DSO and consumers.

Further, the SI perspective and DOI theory have inspired a framework to evaluate the role of the DSO as a change agent for the diffusion of smart grid-innovations to provide a better understanding of the DSO position. The framework has paid attention to three stages of the end user's innovation-decision process: knowledge, persuasion, and implementation. Thus, the thesis has used a form of theoretical triangulation to combine the macro-perspective of SI together with the micro-perspective of DOI. This has been empirically investigated by looking at the supplier-centric model, a disruption to the linkages of the innovation system at the macro level, and the diffusion of innovation for four smart grid-innovations.

The findings suggest that the DSO maintains a relevant, but weakened, position as a change agent following the planned implementation of the supplier-centric market model. Their reduced standing is due to an absent communication link towards the end users, which is the main consequence for the DSOs following the supplier-centric model. Billing and customer contact are expected to be handled by power suppliers, while the DSOs are intended to focus solely on grid-operation and management.

The reduced connection with the end users has implications for their role as change agents, and especially at the knowledge-stage of the end user's innovation-decision process. The stage is considered the most vital stage of the diffusion of innovation and a weakened link reduces the performance of the innovation system and the ability for smart grid-innovations to disperse within the market. Further, to improve their position at the knowledge-stage, the research shows that the DSO needs to strengthen the communication link towards the end users. For example, there are potential economic gains if the DSO is able to advise and assist when it comes to new connections and new constructions. Further, greater awareness of user groups and characteristics of the consumers is seen as beneficial to target selectively engaged consumers, which are the consumers most likely to adopt the smart grid-innovations. The supplier-centric model resolves some uncertainties about responsibility for informing the end users about the smart grid, as this is considered a commercial activity. However, the DSOs will benefit from increased adoption among the end users and should proactively consult consumers. This is seen as an easier task for integrated companies as the flow of information and incentives are tightly connected.

At the persuasion stage, the DSO has strong incentives to motivate the end users to adopt the smart grid-innovations due to their potential operation and management-savings. However, there is uncertainty about the ability to transmit the price-signal with an application of the supplier-centric model. The price-signal is considered the most significant incentive for end users. Uncertainties about the power suppliers' incentives may reduce the diffusion as there are currently missing economic incentives for many of the smart grid-innovations, and especially the absence of demand tariffs. Despite being a monopolistic actor, the DSO may hold greater societal incentives as they function as a government-affiliated intermediary. Thus, the DSOs could benefit from greater cooperation with other market actors to increase the incentives for these participants and help motivate end users to adopt smart grid-innovations.

At the implementation stage, the DSO link towards end user remains strong and unaffected by a transition to a supplier-centric model. However, at this stage the DSOs influence is limited. They are obligated to provide operational services to the end user regardless of whether those decisions are optimal for the grid. This is a natural consequence as the implementation stage succeeds the decision by an end user to adopt an innovation. Thus, to improve their influence at this stage, the DSO can benefit from increased cooperation with other actors in the sector and transfer their competence. Further, maintaining and increasing innovative efforts is seen as relevant for the DSOs as they will need to be up to date on the latest smart grid-innovations regardless of how active they will be towards the consumers. This is due to the operational responsibilities of the DSOs.

The findings imply that the DSOs need to strengthen their communication links towards end users as their connection will remain significant for the future of the smart grid. Further, the study suggest that the DSO will benefit from progressing into an advisory role towards end users and others actor within the system. The interconnectivity of the smart grid could, therefore, be reflected as a greater need for interconnectivity among the actors within the retail electricity market.

References

Ackermann, T., Andersson, G., & Söder, L. (2001). Distributed generation: a definition. *Electric Power Systems Research*, *57*(3), 195–204. https://doi.org/10.1016/S0378-7796(01)00101-8

Albadi, M. H., & El-Saadany, E. F. (2008). A summary of demand response in electricity markets. *Electric Power Systems Research*, *78*(11), 1989–1996. https://doi.org/10.1016/j.epsr.2008.04.002

Annala, S., & Viljainen, S. (2009). Electricity retail market models in Nordic countries — Need for changes? In *2009 6th International Conference on the European Energy Market* (pp. 1–6). https://doi.org/10.1109/EEM.2009.5207187

Annala, S., Lukkarinen, J., Primmer, E., Honkapuro, S., Ollikka, K., Sunila, K., & Ahonen, T. (2018). Regulation as an enabler of demand response in electricity markets and power systems. *Journal of Cleaner Production*, *195*, 1139–1148. https://doi.org/10.1016/j.jclepro.2018.05.276

Arnold, G. W. (2011). Challenges and Opportunities in Smart Grid: A Position Article. *Proceedings of the IEEE*, *99*(6), 922–927. https://doi.org/10.1109/JPROC.2011.2125930

Ballo, I. F. (2015). Imagining energy futures: Sociotechnical imaginaries of the future Smart Grid in Norway. *Energy Research & Social Science*, *9*, 9–20. https://doi.org/10.1016/j.erss.2015.08.015

Cardenas, J. A., Gemoets, L., Ablanedo Rosas, J. H., & Sarfi, R. (2014). A literature survey on Smart Grid distribution: an analytical approach. *Journal of Cleaner Production*, *65*, 202–216. https://doi.org/10.1016/j.jclepro.2013.09.019

Cramton, P. (2017). Electricity market design. *Oxford Review of Economic Policy*, *33*(4), 589–612. https://doi.org/10.1093/oxrep/grx041 de Haan, F. J., & Rotmans, J. (2018). A proposed theoretical framework for actors in transformative change. *Technological Forecasting and Social Change*, *128*, 275–286. https://doi.org/10.1016/j.techfore.2017.12.017

de Reuver, M., van der Lei, T., & Lukszo, Z. (2016). How should grid operators govern smart grid innovation projects? An embedded case study approach. *Energy Policy*, *97*, 628–635. https://doi.org/10.1016/j.enpol.2016.07.011

Dearing, J. W. (2009). Applying Diffusion of Innovation Theory to Intervention Development. *Research on Social Work Practice*, *19*(5), 503–518. https://doi.org/10.1177/1049731509335569

del Río, P., & Bleda, M. (2012). Comparing the innovation effects of support schemes for renewable electricity technologies: A function of innovation approach. *Energy Policy*, *50*, 272–282. https://doi.org/10.1016/j.enpol.2012.07.014

Dosi, G. (1988). The nature of the innovation process. In G. Dosi, C. Freeman, R. R. Nelson, G. Silverberg, & L. Soete (Eds.), *Technical Change and Economic Theory*. London ; New York: Pinter Publishers.

Du, P., & Lu, N. (2011). Appliance Commitment for Household Load Scheduling. *IEEE Transactions on Smart Grid*, *2*(2), 411–419. https://doi.org/10.1109/TSG.2011.2140344

Dunn, B., Kamath, H., & Tarascon, J.-M. (2011). Electrical Energy Storage for the Grid: A Battery of Choices. *Science*, *334*(6058), 928–935. https://doi.org/10.1126/science.1212741

Edquist, C. (1997). Systems of Innovation Approaches - Their Emergence and Characteristics. In C. Edquist (Ed.), *Systems of innovation: technologies, institutions, and organizations* (pp. 1–35). London ; Washington: Pinter.

Edquist, C. (2005). Systems of Innovation: Perspectives and Challenges. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), *The Oxford handbook of innovation* (pp. 181–208). Oxford: Oxford University Press.

Eid, C., Codani, P., Perez, Y., Reneses, J., & Hakvoort, R. (2016). Managing electric flexibility from Distributed Energy Resources: A review of incentives for market design. *Renewable and Sustainable Energy Reviews*, *64*, 237–247. https://doi.org/10.1016/j.rser.2016.06.008

El-Khattam, W., & Salama, M. M. . (2004). Distributed generation technologies, definitions and benefits. *Electric Power Systems Research*, *71*(2), 119–128. https://doi.org/10.1016/j.epsr.2004.01.006

Energi Norge. (2018). Forslag til handlingsplan for innføring av en regning i sluttbrukermarkedet. Energi Norge. Retrieved from https://www.energinorge.no/contentassets/fa9ca0e9ff0d4b3a97d94dfbf0b8b107/2018-01-17---energi-norge---innspill-til-fasevis-plan-for-innforing-av-enfaktura.pdf

Energi21. (2014). *Strategi 2014: Nasjonal strategi for forskning, utvikling, demonstrasjon og kommersialisering av ny energiteknologi* (Consultation report No. 2). Oslo: Energi21.

Erlinghagen, S., & Markard, J. (2012). Smart grids and the transformation of the electricity sector: ICT firms as potential catalysts for sectoral change. *Energy Policy*, *51*, 895–906. https://doi.org/10.1016/j.enpol.2012.09.045

Fagerberg, J. (2003). Schumpeter and the revival of evolutionary economics: an appraisal of the literature. *Journal of Evolutionary Economics*, *13*(2), 125–159. https://doi.org/10.1007/s00191-003-0144-1

Fagerberg, J. (2005). Innovation: A Guide to the Literature. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), *The Oxford handbook of innovation* (pp. 1–27). Oxford University Press.

Fagerberg, J., Martin, B. R., & Andersen, E. S. (2013). Innovation Studies: Towards a New Agenda. In J. Fagerberg, B. R. Martin, & E. S. Andersen (Eds.), *Innovation studies: evolution and future challenges* (1st ed). Oxford: Oxford University Press. Retrieved from DOI:10.1093/acprof:oso/9780199686346.003.0001

Faruqui, A., & Sergici, S. (2010). Household response to dynamic pricing of electricity: a survey of 15 experiments. *Journal of Regulatory Economics*, *38*(2), 193–225. https://doi.org/10.1007/s11149-010-9127-y

FME CenSES. CenSES Energy demand projections towards 2050 - Reference path (2015). Centre for Sustainable Energy Studies. Retrieved from https://www.ntnu.no/documents/7414984/1265644753/Position-paper_Energy-Projections_utenbleed.pdf/b39bc144-cff6-46c3-82d9-37b1f8b2e04f

Foxon, T. J., Gross, R., Chase, A., Howes, J., Arnall, A., & Anderson, D. (2005). UK innovation systems for new and renewable energy technologies: drivers, barriers and systems failures. *Energy Policy*, *33*(16), 2123–2137. https://doi.org/10.1016/j.enpol.2004.04.011

Friis, F., & Haunstrup Christensen, T. (2016). The challenge of time shifting energy demand practices: Insights from Denmark. *Energy Research & Social Science*, *19*, 124–133. https://doi.org/10.1016/j.erss.2016.05.017

Furlan, C., & Mortarino, C. (2018). Forecasting the impact of renewable energies in competition with non-renewable sources. *Renewable and Sustainable Energy Reviews*, *81*, 1879–1886. https://doi.org/10.1016/j.rser.2017.05.284

Gangale, F., Mengolini, A., & Onyeji, I. (2013). Consumer engagement: An insight from smart grid projects in Europe. *Energy Policy*, *60*, 621–628. https://doi.org/10.1016/j.enpol.2013.05.031

Ghaderi, M., & Tahmasebi, A. (2014). Battery energy storage systems diffusion towards the smart grids: the case of Italy and the US.

Gladwin, D., Todd, R., Forsyth, A. J., Foster, M. P., Strickland, D., Feehally, T., & Stone, D. A. (2016). Battery energy storage systems for the electricity grid: UK research facilities. In *8th IET International Conference on Power Electronics, Machines and Drives (PEMD 2016)* (pp. 6 .-6 .). Glasgow, UK: Institution of Engineering and Technology. https://doi.org/10.1049/cp.2016.0257

Goulden, M., Bedwell, B., Rennick-Egglestone, S., Rodden, T., & Spence, A. (2014). Smart grids, smart users? The role of the user in demand side management. *Energy Research & Social Science*, *2*, 21–29. https://doi.org/10.1016/j.erss.2014.04.008

Greening, L. A. (2010). Demand response resources: Who is responsible for implementation in a deregulated market? *Energy*, *35*(4), 1518–1525. https://doi.org/10.1016/j.energy.2009.12.013

Grijalva, S., & Tariq, M. U. (2011). Prosumer-based smart grid architecture enables a flat, sustainable electricity industry. In *ISGT 2011* (pp. 1–6). Anaheim, CA, USA: IEEE. https://doi.org/10.1109/ISGT.2011.5759167

Grubler, A. (2012). Energy transitions research: Insights and cautionary tales. *Energy Policy*, *50*, 8–16. https://doi.org/10.1016/j.enpol.2012.02.070

Gungor, V. C., Sahin, D., Kocak, T., Ergut, S., Buccella, C., Cecati, C., & Hancke, G. P. (2011). Smart Grid Technologies: Communication Technologies and Standards. *IEEE Transactions on Industrial Informatics*, *7*(4), 529–539. https://doi.org/10.1109/TII.2011.2166794

Gupta, B. B., & Quamara, M. (2018). An overview of Internet of Things (IoT): Architectural aspects, challenges, and protocols. *Concurrency and Computation: Practice and Experience*, e4946. https://doi.org/10.1002/cpe.4946

Haakonsson, S. J., & Slepniov, D. (2018). Technology Transmission Across National Innovation Systems: The Role of Danish Suppliers in Upgrading the Wind Energy Industry in China. *The European Journal of Development Research*, *30*(3), 462–480. https://doi.org/10.1057/s41287-018-0128-5

Haas, P. M. (1992). Introduction: Epistemic Communities and International Policy Coordination. *International Organization*, *46*(1), 1–35.

Hafslund. (2018). *Kraftsystemutredning for Oslo, Akershus og Østfold 2018-2038*. Oslo: Hafslund. Retrieved from https://assets.ctfassets.net/p14w1ia3hr36/5rEIzlSbNS86agkkwuEoaG/38d5eaf946852b9c18ff3cfe868ee49c/kraftsystemutredning_HN_Hovedrapport_2018_2038.pdf

Haley, B. (2018). Integrating structural tensions into technological innovation systems analysis: Application to the case of transmission interconnections and renewable electricity in Nova Scotia, Canada. *Research Policy*, *47*(6), 1147–1160. https://doi.org/10.1016/j.respol.2018.04.004

Hansen, M., & Hauge, B. (2017). Prosumers and smart grid technologies in Denmark: developing user competences in smart grid households. *Energy Efficiency*, *10*(5), 1215–1234. https://doi.org/10.1007/s12053-017-9514-7

Hofman, P. S., & Elzen, B. (2010). Exploring system innovation in the electricity system through sociotechnical scenarios. *Technology Analysis & Strategic Management*, *22*(6), 653–670. https://doi.org/10.1080/09537325.2010.496282

Hoppmann, J., Volland, J., Schmidt, T. S., & Hoffmann, V. H. (2014). The economic viability of battery storage for residential solar photovoltaic systems – A review and a simulation model. *Renewable and Sustainable Energy Reviews*, *39*, 1101–1118. https://doi.org/10.1016/j.rser.2014.07.068

Islam, T. (2014). Household level innovation diffusion model of photo-voltaic (PV) solar cells from stated preference data. *Energy Policy*, *65*, 340–350. https://doi.org/10.1016/j.enpol.2013.10.004

Jacobsson, S., & Bergek, A. (2011). Innovation system analyses and sustainability transitions: Contributions and suggestions for research. *Environmental Innovation and Societal Transitions*, *1*(1), 41–57. https://doi.org/10.1016/j.eist.2011.04.006

Johannessen, A., Tufte, P. A., & Christoffersen, L. (2010). *Introduksjon til samfunnsvitenskapelig metode*. Oslo: Abstrakt forlag.

Johansson, P., Vendel, M., & Nuur, C. (2018). *The transition towards solar power; business as usual or a new role for incumbent grid operators?*

Karakaya, E., Hidalgo, A., & Nuur, C. (2015). Motivators for adoption of photovoltaic systems at grid parity: A case study from Southern Germany. *Renewable and Sustainable Energy Reviews*, *43*, 1090–1098. https://doi.org/10.1016/j.rser.2014.11.077

Kebede, K. Y., & Mitsufuji, T. (2017). Technological innovation system building for diffusion of renewable energy technology: A case of solar PV systems in Ethiopia. *Technological Forecasting and Social Change*, *114*, 242–253. https://doi.org/10.1016/j.techfore.2016.08.018

Kinnunen, J. (1996). Gabriel Tarde as a Founding Father of Innovation Diffusion Research. *Acta Sociologica*, *39*(4), 431–442.

Kivimaa, P. (2014). Government-affiliated intermediary organisations as actors in system-level transitions. *Research Policy*, *43*(8), 1370–1380. https://doi.org/10.1016/j.respol.2014.02.007

Kline, S. J., & Rosenberg, N. (1986). *An Overview of Innovation*. https://doi.org/10.1142/9789814273596_0009

Lund, P. D. (2009). Effects of energy policies on industry expansion in renewable energy. *Renewable Energy*, *34*(1), 53–64. https://doi.org/10.1016/j.renene.2008.03.018

Lundblad, J. P. (2003). A review and critique of Rogers' diffusion of innovation theory as it applies to organizations. *Organization Development Journal*, *21*(4), 50–64.

Lundvall, B.-Å. (Ed.). (1992). *National systems of innovation: towards a theory of innovation and interactive learning*. London : New York: Pinter Publishers ; Distributed exclusively in the USA and Canada by St. Martin's Press.

Luo, X., Wang, J., Dooner, M., & Clarke, J. (2015). Overview of current development in electrical energy storage technologies and the application potential in power system operation. *Applied Energy*, *137*, 511–536. https://doi.org/10.1016/j.apenergy.2014.09.081

Lyytinen, K., & Damsgaard, J. (2001). What's Wrong with the Diffusion of Innovation Theory? In M. A. Ardis & B. L. Marcolin (Eds.), *Diffusing Software Product and Process Innovations* (Vol. 59, pp. 173–190). Banff, Canada: Springer US. Retrieved from https://link-springer-com.ezproxy.uio.no/book/10.1007%2F978-0-387-35404-0

Majumdar, S., Guha, S., & Marakkath, N. (2015). Technology and Innovation for Social Change: An Introduction. In S. Majumdar, S. Guha, & N. Marakkath (Eds.), *Technology and Innovation for Social Change* (pp. 1–3). New Delhi: Springer India. https://doi.org/10.1007/978-81-322-2071-8_1

Morgan, M. G., Apt, J., Lave, L., Ilic, M., Sirbu, M., & Peha, J. (2009). The Many Meanings of'Smart Grid'.

Moum, A., Hauge, Å., & Thomsen, J. (2017). *Four Norwegian Zero Emission Pilot Buildings – Building Process and User Evaluation*.

Mulder, G., Six, D., Claessens, B., Broes, T., Omar, N., & Mierlo, J. V. (2013). The dimensioning of PV-battery systems depending on the incentive and selling price conditions. *Applied Energy*, *111*, 1126–1135. https://doi.org/10.1016/j.apenergy.2013.03.059

Multiconsult. (2014). *Markedsundersøkelse: barrierer og muligheter innen byggsektoren for å ta i bruk solenergi i Norge* (pp. 1–21). Oslo: Multiconsult.

Multiconsult, & Asplan Viak. (2018). *Solcellesystemer og sol i systemet* (No. 1) (pp. 1–88). Solenergiklyngen. Retrieved from http://solenergiklyngen.no/app/uploads/sites/4/180313-rapport_solkraft-markedsutvikling-2017-endelig.pdf

Musiolik, J., & Markard, J. (2011). Creating and shaping innovation systems: Formal networks in the innovation system for stationary fuel cells in Germany. *Energy Policy*, *39*(4), 1909–1922. https://doi.org/10.1016/j.enpol.2010.12.052

Naber, R., Raven, R., Kouw, M., & Dassen, T. (2017). Scaling up sustainable energy innovations. *Energy Policy*, *110*, 342–354. https://doi.org/10.1016/j.enpol.2017.07.056

Negro, S. O., Alkemade, F., & Hekkert, M. P. (2012). Why does renewable energy diffuse so slowly? A review of innovation system problems. *Renewable and Sustainable Energy Reviews*, *16*(6), 3836–3846. https://doi.org/10.1016/j.rser.2012.03.043

Nelson, R. R., & Rosenberg, N. (1993). Technical Innovation and National Systems. In R. R. Nelson (Ed.), *National innovation systems: a comparative analysis* (pp. 3–22). New York: Oxford University Press.

Nordic Council of Ministers. (2017). *Demand side flexibility in the Nordic electricity market*. Nordic Council of Ministers. https://doi.org/10.6027/TN2017-564

Nordic Energy Regulators. (2011). *Rights and obligations of DSOs and suppliers in the customer interface* (2011 No. 4). Copenhagen: Nordic Energy Regulators.

Nordic Energy Regulators. (2016). The work towards a Nordic retail market - current state and development (pp. 1–27). Presented at the Workshop - 3rd of November 2016, Copenhagen: Nordic Energy Regulators. Retrieved from http://www.nordicenergyregulators.org/wp-content/uploads/2017/02/Towards-a-supplier-centric-model.pdf

NVE. Forslag til endring i forskrift om kontrollav nettvirksomhet: Utforming av uttakstariffer i distribusjonsnettet (2017). Oslo: NVE. Retrieved from http://webfileservice.nve.no/API/PublishedFiles/Download/201706767/2242754

NVE. (2017b). *Utvikling i nøkkeltal for nettselskap* (2017 No. 89). Oslo: NVE. Retrieved from http://publikasjoner.nve.no/rapport/2017/rapport2017_89.pdf

NVE. (2018). *Strømforbruk i Norge mot 2035* (No. 43–2018) (pp. 1–19). Oslo: NVE. Retrieved from http://publikasjoner.nve.no/rapport/2018/rapport2018_43.pdf

Olje- og energidepartementet. (2016). Kraft til endring - Energipolitikken mot 2030. Retrieved from https://www.regjeringen.no/contentassets/31249efa2ca6425cab08130b35ebb997/no/pdfs/stm201520160025000dddpdfs.pdf

Olsen, L. E. (2018, October). *Kunden ASKO mot klimanøytralitet i 2020*. Presented at the Smartgridkonferansen 2018, Trondheim.

Owusu, P. A., & Asumadu-Sarkodie, S. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. *Cogent Engineering*, *3*(1). https://doi.org/10.1080/23311916.2016.1167990

Parag, Y., & Sovacool, B. K. (2016). Electricity market design for the prosumer era. *Nature Energy*, *1*(4), 16032. https://doi.org/10.1038/nenergy.2016.32

Pepermans, G., Driesen, J., Haeseldonckx, D., Belmans, R., & D'haeseleer, W. (2005). Distributed generation: definition, benefits and issues. *Energy Policy*, *33*(6), 787–798. https://doi.org/10.1016/j.enpol.2003.10.004

Ringdal, K. (2013). *Enhet og mangfold: samfunnsvitenskapelig forskning og kvantitativ metode*. Fagbokforlaget. Retrieved from https://books.google.no/books?id=7_h6MwEACAAJ

Ritchie, J., & Lewis, J. (2003). Generalising from Qualitative Research. In J. Ritchie & J. Lewis (Eds.), *Qualitative Research Practice: A Guide for Social Science Students and Researchers*. SAGE.

Roberts, B. P., & Sandberg, C. (2011). The Role of Energy Storage in Development of Smart Grids. *Proceedings of the IEEE*, *99*(6), 1139–1144. https://doi.org/10.1109/JPROC.2011.2116752

Rogers, E. M. (1962). *Diffusion of innovations.* New York: Free Press of Glencoe.

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed). New York: Free Press.

Römer, B., Reichhart, P., Kranz, J., & Picot, A. (2012). The role of smart metering and decentralized electricity storage for smart grids: The importance of positive externalities. *Energy Policy*, *50*, 486–495. https://doi.org/10.1016/j.enpol.2012.07.047

Ruggiero, S., Varho, V., & Rikkonen, P. (2015). Transition to distributed energy generation in Finland: Prospects and barriers. *Energy Policy*, *86*, 433–443. https://doi.org/10.1016/j.enpol.2015.07.024

Shafie-Khah, M., & Siano, P. (2018). A Stochastic Home Energy Management System Considering Satisfaction Cost and Response Fatigue. *IEEE Transactions on Industrial Informatics*, *14*(2), 629–638. https://doi.org/10.1109/TII.2017.2728803

Siano, P. (2014). Demand response and smart grids—A survey. *Renewable and Sustainable Energy Reviews*, *30*, 461–478. https://doi.org/10.1016/j.rser.2013.10.022

Silverman, D. (2000). *Doing qualitative research: a practical handbook*. London ; Thousand Oaks, Calif: Sage Publications.

Skjølsvold, T. M., Ryghaug, M., & Dugstad, J. (2013). Building on Norway's Energy Goldmine: Policies for Expertise, Export, and Market Efficiencies. In E. Michalena & J. M. Hills (Eds.), *Renewable Energy Governance* (Vol. 23, pp. 337–349). London: Springer London. https://doi.org/10.1007/978-1-4471-5595-9_20

Snape, D., & Spencer, L. (2003). The Foundations of Qualitative Research. In J. Ritchie & J. Lewis (Eds.), *Qualitative Research Practice: A Guide for Social Science Students and Researchers* (pp. 1–23). SAGE Publications.

Stephens, J., Wilson, E., Peterson, T., & Meadowcroft, J. (2013). Getting Smart? Climate Change and the Electric Grid. *Challenges*, *4*(2), 201–216. https://doi.org/10.3390/challe4020201

Stoneman, P. (Ed.). (1995). Introduction. In *Handbook of the economics of innovations and technological change* (pp. 1–13). Oxford, UK ; Cambridge, Mass: Blackwell.

Su, W., Eichi, H., Zeng, W., & Chow, M.-Y. (2012). A Survey on the Electrification of Transportation in a Smart Grid Environment. *IEEE Transactions on Industrial Informatics*, *8*(1), 1–10. https://doi.org/10.1109/TII.2011.2172454

Sun, Y., Lampe, L., & Wong, V. W. S. (2015). Combining electric vehicle and rechargeable battery for household load hiding. In *2015 IEEE International Conference on Smart Grid Communications (SmartGridComm)* (pp. 611–616). Miami, FL, USA: IEEE. https://doi.org/10.1109/SmartGridComm.2015.7436368

Teleke, S., Baran, M. E., Bhattacharya, S., & Huang, A. Q. (2010). Rule-Based Control of Battery Energy Storage for Dispatching Intermittent Renewable Sources. *IEEE Transactions on Sustainable Energy*, *1*(3), 117–124. https://doi.org/10.1109/TSTE.2010.2061880

Toews, D. (2003). The New Tarde: Sociology After the End of the Social. *Theory, Culture & Society*, *20*(5), 81–98. https://doi.org/10.1177/02632764030205004

Tran, M. (2012). Agent-behaviour and network influence on energy innovation diffusion. *Communications in Nonlinear Science and Numerical Simulation*, *17*(9), 3682–3695. https://doi.org/10.1016/j.cnsns.2012.01.016

Verbong, Geert P.J., Beemsterboer, S., & Sengers, F. (2013). Smart grids or smart users? Involving users in developing a low carbon electricity economy. *Energy Policy*, *52*, 117–125. https://doi.org/10.1016/j.enpol.2012.05.003

Verbong, G.P.J., & Geels, F. W. (2010). Exploring sustainability transitions in the electricity sector with socio-technical pathways. *Technological Forecasting and Social Change*, *77*(8), 1214–1221. https://doi.org/10.1016/j.techfore.2010.04.008

Vestby, L., & Dvergnes, A. (2017). *Går samfunnet i pluss med plusskunder?* (Master Thesis). Norges Handelshøyskole, Bergen.

von der Fehr, N.-H. M., & Hansen, P. V. (2010). Electricity Retailing in Norway. *The Energy Journal*, *31*(1), 25–45.

Wissner, M. (2011). The Smart Grid – A saucerful of secrets? *Applied Energy*, *88*(7), 2509–2518. https://doi.org/10.1016/j.apenergy.2011.01.042

World Bank. (2005). Primer on Demand-Side Management : With an Emphasis on Price-Responsive Programs. The World Bank.

WWF, & Accenture. (2016). *Mot Lysere Tider: Solkraft i Norge – Fremtidige muligheter for verdiskaping*. Retrieved from https://d1rirzyrd4ly69.cloudfront.net/downloads/160315_wwf_a4_screen_spread.pdf

Yin, R. K. (2014). *Case Study Research*. SAGE Publications. Retrieved from https://books.google.no/books?id=Ace0kgEACAAJ

Zhao, H., Wu, Q., Hu, S., Xu, H., & Rasmussen, C. N. (2015). Review of energy storage system for wind power integration support. *Applied Energy*, *137*, 545–553. https://doi.org/10.1016/j.apenergy.2014.04.103

Appendix I – Interview Guide

The interview guide is translated from Norwegian to English. The focus areas and questions asked differed over time and based on the position and role of the respondent. All subjects and questions are included in this appendix.

Introduction:

Hello and thank you for attending this interview. Before we start I wish to inform you about the background and purpose of this research.

Today's interview will be used as data material in my master's thesis which is about DSOs, customer contact and smart grid-innovations in a supplier-centric market model. The thesis is the final requirement for a master's degree at TIK centre for Technology, Innovation and Culture. I am specialising in innovation in my degree. The research is also a part of a project called "Fremtidens Nett" coordinated by Adapt Consulting. The purpose of the research is to look at the impact of the supplier-centric model on smart grid-innovations and customer contact. In particular, I wish to look at the impact of the supplier-centric model on the retail electricity market as an innovation system. My research question is as follows:

How does the supplier-centric model effect the role of DSOs as a change agent for the diffusion of smart grid-innovations?

Personally, I am interested in the sector and the ongoing changes. However, I have no experience within the sector and no assumptions about the possible outcome of the research. Your reflections about these topics will give me a better understanding of the sector, together with the other interviews I have conducted. Your name and other personal characteristics will be anonymised.

I wish to use an audio recorder if that is OK? The questions are structured in a semi-structured way. This means that there will be some topics of interest, which you are allowed to use as much time you feel necessary to reflect around the subject or particular questions. I will try to steer the conversation to best be able to gain relevant information to answer the research question. Are there any questions before we begin?

Topic	Questions	Key words
Organisation	Could you briefly describe the organisation? Could you describe your position and experience from the sector? Could you describe the position of the DSO within the retail electricity market? If DSO: Does the DSO have prosumers? Does the DSO have a research or innovation department? Are there any projects you wish to highlight?	Number of customers Customer types Geography/location
Supplier-centric model	Could you describe what you believe to be the main changes following an implementation of the supplier-centric model? How is the DSO affected by the supplier-centric model? How are the other actors in	Customer contact Combined billing ElHub Universal delivery Rights and obligations Competence

	the retail electricity market affected by the supplier-centric model? Are there any uncertainties about the supplier-centric model? Will the supplier-centric model affect the competence of the DSOs?	
Customer contact	Is customer contact important for the DSO? Why? Is the customer contact affected by the supplier-centric model? How? What aspects of customer contact will be important in the future? Do you have any experiences from combined billing? Are you experiencing any changes in the sector when it comes to customer contact?	Price-signal Incentives Knowledge Flow of information Advisory Competition Reputation
Consumers	Why is customer contact important for the customer? Are you experiencing any changes when it comes to the	Connections Power outage Tariffs

	customers? How do you expect the customer to behave in the future?	Consumption EVs Innovations Prosumers
The future (smart) grid	What changes are likely to happen to the grid operation? How will the DSO role look in the future? How will the smart grid be for the user? What is your impression of smart grid-innovations in the sector?	Prosumers Demand tariffs Battery storage Aggregators Alternatives to grid Electrification Demand response Higher investments Energy management systems
DSO adjustments for the future	How is the DSO working to adjust towards the future? How is the DSO working to maintain customer contact? Are there any particular solutions for communication with the customer you wish to highlight?	Communication channel Price-signal distribution Chatbots App-solutions Text-messaging Energy management systems