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The Consequences of the Smart Grid for the Business Model of Electricity Firms

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Abstract

The smart grid could revolutionize the electricity sector when it stimulates customer empowerment and allows new players such as ICT firms to participate. A key question is whether electricity firms would either benefit or lose from its deployment, because their existing business model might be at risk. This paper seeks to explain under which conditions smart grid deployment will have an enabling and/or constraining effect on electricity firms? engagement in business model innovation. Critically reviewing existing studies on the smart grid, the paper investigates the consequences of smart grid deployment on each of the elements of the business model: value proposition, value creation and delivery, and profit model. The main argument posited is that while there are many reasons to believe that electricity firms will embrace the smart grid and innovate their business model towards sustainability, there are still many uncertainties related to government support, new entrants, and consumer engagement that might induce them to wait with business model innovation until such uncertainties have been resolved. The paper contributes to the emerging literature on business models for sustainable innovation by identifying potential new trajectories for the transition of electricity firms as well as areas for future research within this topic area.

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Keywords: smart grid; disruptive technology; business models; sustainable innovation; electricity firms

1. Introduction

> We are convinced that it's necessary to respond to dramatically altered global energy markets, technical innovation, and more diverse customer expectations with a bold new beginning. E.ON's existing broad business model can no longer properly address these new challenges. Therefore, we want to set up our business significantly different. (E.ON's CEO Johannes Teyssen, November 30th, 2014)

Over the past decades, innovation in the electricity sector has mainly concerned power generation. Various generation sources such as renewables have been developed, while the transmission and distribution structure remained largely unchanged (Erlinghagen and Markard, 2012). The emergence of the 'smart grid' forms a break with this trend, as it has the potential to revolutionize how all the separate parts of the electricity value chain as well as the interaction between them function (Battaglini et al., 2009; Clastres, 2011; Römer et al., 2012). The smart grid has been defined as "an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end-users" (IEA, 2011, p.6). What makes the grid smarter – i.e. weaving information and communication technology (ICT) into it – holds great potential for an optimized balancing of the electricity network and the uptake of distributed energy, and could therefore be a driver for sustainable innovation (Boons and Lüdeke-Freund, 2013).

The smart grid would revolutionize the electricity sector when it stimulates customer empowerment. Customers would not only have more information about their electricity consumption, allowing them to better control it, but they could also more easily generate their own electricity using renewable, distributed sources to become less dependent on electricity firms (Clastres, 2011; Geelen et al., 2013; Römer et al., 2012). A key question is, therefore, whether electricity firms either stand to benefit from the smart grid from an improved efficiency of the electricity network, or stand to lose due to a decline in demand from customer empowerment. As the epigraph illustrates, the traditional business model of electricity firms, based on maximizing electricity production to achieve economies of scale, is at risk (Fox-Penner, 2010; Lehr, 2013; Richter, 2013). Whereas the smart grid seems to push electricity firms to develop more sustainable business models, the question remains whether they will embrace this turn towards sustainability, or not (Bocken et al., 2014; Bohnsack et al., 2014; Boons and Lüdeke-Freund, 2013; Boons et al., 2013).

While electricity firms will most likely play a key role in smart grid deployment, what this role will be exactly is not yet clear. Since electricity firms have wide access to consumers, they can be important for the success or failure of governments' efforts to create a smart grid (Cardenas et al., 2014). Yet, when they fail to involve consumers or do not perceive enough incentives to invest in the smart grid, they could hinder the progress and defer the governments' targets as well. Despite the fact that many of the technologies that together form the smart grid are already in place, so far electricity firms seem to have failed in designing an appropriate mechanism to generate revenue out of these technologies (Catalin et al., 2014; Mah et al., 2013). At the same time, they have opened the door to new players such as ICT firms and start-ups whose entering of the electricity market might attenuate their competitiveness. To create more insight into the position of electricity firms in relation to smart grid, in this paper we seek to explain under which conditions smart grid deployment will have an enabling and/or constraining effect on their engagement in developing business models for sustainable innovation.

The business model concept explains how a firm creates economic value out of a technology (Baden-Fuller and Haefliger, 2013; Bohnsack et al., 2014; Chesbrough and Rosenbloom, 2002). Sometimes new technologies have disruptive effects on the established business model of industry incumbents, which force them to innovate their business models

(Chesbrough, 2010; Sabatier et al., 2012; Tongur and Engwall, 2014). Disruptive technologies may change the customer perception of value (Markides, 2006), or demand incumbents to develop new capabilities to deliver value to customers (Anderson and Tushman, 1990). Incumbents face several barriers to distinguish these effects and design the appropriate business model. Limited cognitive capacity of managers prevents them from thinking beyond existing routines and distinguishing the changes needed (Chesbrough, 2010). Also, fear of losing current revenue deters incumbents from developing new business models (Amit and Zott, 2001; Sosna et al., 2010). To overcome these barriers, the business model lens can be used to identify changes needed for a firm to remain profitable (Chesbrough, 2010; Osterwalder, 2004). In this paper, we use this lens to understand the challenges and opportunities of smart grid deployment for incumbent electricity firms' business models. Based on a critical review of existing studies on the smart grid, we investigate the consequences of smart grid deployment on each of the elements of the business model: value proposition, value creation and delivery, and profit model (Bocken et al., 2014; Bohnsack et al., 2014). We aim to create insight not only into how a transition of the electricity sector based on smart grid deployment could threaten electricity firms' position in this sector, but also how these firms could use the smart grid infrastructure to their advantage.

As main argument we posit that while there are many reasons to believe that electricity firms will embrace the smart grid and change their business model to be able to integrate this sustainable innovation (Boons and Lüdeke-Freund, 2013), there are still many uncertainties related to government support, new entrants, and consumer engagement that might induce them to wait with sustainable business model innovation until such uncertainties have been resolved. In essence, the smart grid is a systemic technology that can only come to fruition if other complementary technologies, infrastructures and institutions develop simultaneously (Chesbrough and Teece, 2002; Garud and Kumaraswamy, 1995).

Important boundary conditions for electricity firms in this regard include: government support not only for the roll-out of an advanced metering infrastructure, but also for renewable energy technologies and electric vehicles; the entering of ICT firms for complementary assets (Erlinghagen and Markard, 2012); and customer engagement in the form of demand response to shift peak load and balance the grid (Gangale et al., 2013; Geelen et al., 2013; He et al., 2013). While previous studies mainly addressed the effects of the smart grid on the industry level, and assessed the effectiveness of one of the possible new sources of revenue generation, a comprehensive study on the firm-level about impact of the smart grid on electricity firms' business models is still rare. By addressing this gap, this paper contributes to the emerging literature on business models for sustainable innovation in general (Bocken et al., 2014; Bohnsack et al., 2014; Boons and Lüdeke-Freund, 2013) and for electricity firms in specific (Fox-Penner, 2010; Giordano and Fulli, 2011; He et al., 2013; Lehr, 2013) by identifying potential new trajectories for the transition of electricity firms as well as areas for future research within this topic area.

2. Methodology

The purpose of this study is to review the smart grid publications through the business model lens. A systematic review of all business model publications is beyond the scope of this paper and our focus is on publications on the smart grid. In order to form our business model framework properly, having used the Google Scholar's citation indexes, we started to review the most cited publications on business models and enriched our review with some cross referencing. Overall, we reviewed 20 papers about business models and business model innovation. Then, on smart grid publications a systematic review conducted as well. We started our query with the keyword "smart grid" in the abstract in the following databases: Science Direct (Publisher: Elsevier) restricted to sources in the areas of: Business, Management and Accounting, Economics, Econometrics and Finance; Business Source Complete (Aggregator: EBSCO); and Emerald Management Plus (Publisher: Emerald). No constraint was set for the earliest year of publication papers and all types of sources including academic peer-reviewed paper, magazine and newspaper articles, and official reports of international institutions were reviewed to maximize the comprehensiveness of the review.

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Insert Figure 1 about here

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In the first phase, we came up with 150 results. Having screened these papers, we could identify the most challenging issues of the smart grid deployment for electricity firms' business models. The main issues included: demand response, consumer empowerment, entrance of new actors, energy services, integration of distributed energy sources, and a need for new regulation. Based on these emerging issues, we were able to decide on the appropriate business model framework. Going back to the business model literature, we decided on the framework depicted in Figure 1. In the second phase, we narrowed down the total set of 150 papers by adopting the business model lens to select those papers which focused on (one of the) three main elements of business models that we identified from the business model literature: value proposition, value creation and delivery, and profit model (Bocken et al., 2014; Bohnsack et al., 2014). As a result, we critically reviewed 32 papers about the consequences of the smart grid technology on electricity firms' business models.

3. The business model lens

3.1. A review of the business model concept

The business model has been defined as the way a firm creates and captures value (Osterwalder, 2004; Teece, 2010). Like all models which are used to simplify reality, business models have been used to simplify what is happening in a firm, in order to make it visible, analyzable and manageable (Osterwalder, 2004). The business model concept is built upon two well-known theories of management: the resource-based view and transaction cost economics. The underlying logic of most business model frameworks is to find a unique combination of the firm's resources and capabilities, and then to determine the most efficient way to structure the transactions between these resources and capabilities to generate value for the firm and its customers (DaSilva and Trkman, 2013).

When a new technology emerges, the business model concept can help managers delineate how to benefit from implementing the new technology. Therefore, some scholars defined the business model as a mediator between technological innovation and economic value creation (Baden-Fuller and Haefliger, 2013; Chesbrough and Rosenbloom, 2002). It provides firms with an analytical tool to recognize challenges imposed by a new technology and helps them to identify which capabilities they need to acquire and how their current activities should change to enable them to achieve their desired economic value (Osterwalder, 2004).

To assist firms in developing or changing their business models, many frameworks have been proposed that give an outline of the main elements of a business model (Baden-Fuller and Haefliger, 2013; Chesbrough and Rosenbloom, 2002; Osterwalder, 2004; Teece, 2010). Despite differences between these frameworks, the commonly recurring components have been summarized as follows: value proposition, value creation and delivery and profit model (Bocken et al., 2014; Bohnsack et al., 2014). Underneath each of these components, different elements reside which might be of varying importance across industries. To explain the consequences of the smart grid technology, in this paper we will focus on those elements which seem most relevant for electricity firms in terms of how they are affected by smart grid technology. We note that the smart grid is not only a potentially disruptive technology, but also one that specifically pushes electricity firms to reckon with sustainability, as it can reduce environmental impact and stimulate social innovation through customer empowerment (Bocken et al., 2014; Boons and Lüdeke-Freund, 2013).

As Figure 1 illustrates, we will start with the value proposition elements: i.e. customers' changes in the perception of value and change in the relationship between electricity firms and customers. Then, we will argue how electricity firms' value creation and delivery elements are changing, including the available resources and capabilities, the partners, and the position in the value network. Finally, we will discuss the impact of smart grid deployment on the cost structure of electricity firms and possible new ways of revenue generation. Obviously, there are interdependencies between these different elements; proposing a new profit model could not be done without considering changes in the value proposition and value creation and delivery elements, for example.

Despite its potential role in a firm's success, not all the firms are as eager to change their business model. Incumbents tend to resist radically changing their business model when they face a new technology and rather integrate the technology in their current business model instead. In contrast, new entrants are more likely to come up with a new business model as they are not hindered by an existing business model (Bohnsack et al., 2014; Sosna et al., 2010). Incumbent firms thus face specific barriers to business model innovation, as discussed in the next section.

3.2. Barriers to business model innovation

Business model innovation has been defined as "the discovery of a fundamentally different business model in an existing business", which could lead to economic value creation (Markides, 2006, p.20). It can include a redefinition of the value proposition (Tongur and Engwall, 2014), a new configuration of value creation and delivery elements (Markides, 2006), or a discovery of new sources of value (Chesbrough, 2010). While business model innovation could be initiated by a new entrant or an incumbent (Sosna et al., 2010), it seems particularly challenging for incumbents to renew their business models (Chesbrough, 2010). Incumbents' barriers to business model innovation are both conscious and unconscious; that is, their hesitation in part stems from a fear of losing out on current revenue streams (Amit and Zott, 2001; Sosna et al., 2010) and in part from managers' cognitive constraints (Chesbrough and Rosenbloom, 2002; Chesbrough, 2010). It has therefore been argued that incumbents face a business model dilemma; even though a disruptive technology might ask for a new business model, incumbents profiting from the existing technology will face difficulties in changing their business model accordingly (Tongur and Engwall, 2014).

The unwillingness to overhaul resources and capabilities and change established revenue generation mechanisms as well as uncertainty about a new business model's functioning hinders incumbents' business model innovation (Sosna et al., 2010). A lower anticipated rate of profitability of a new business model in the early phases deters managers from engaging in its development. Moreover, incumbent managers may not have enough creativity and cognitive ability to innovate their business model. As Chesbrough (2010) argues, an incumbent's business model is established based on a set of norms and beliefs that over the years becomes the dominant logic of the managers (cf. Prahalad and Bettis, 1986). It guides managers' actions, filters the information they capture from the environment and shapes their perception of risks and opportunities of environmental phenomena, and thus limits their cognitive capacity (Chesbrough, 2010; Sosna et al., 2010).

For incumbents, one of the main triggers of business model innovation is the emergence of disruptive technologies (Chesbrough, 2010). Disruptive technologies can be defined from two different points of view: capability-based and market-based (Bergek et al., 2013). From a capability-based view, disruptive technologies have been defined as "technological discontinuities" that, in order to be exploited, demand fundamental changes in the firm's capabilities (Anderson and Tushman, 1990). From a market-based view, disruptive technologies are those which change the desirability criteria of a product's performance in the eyes of the customers (Markides, 2006). Based on the observation that certain industries, such as the pharmaceutical industry, seem to have been immune to disruptive technologies, Sabatier and Mangematin (2012) argue that new technologies can only be considered as discontinuous when they challenge the dominant business model of an industry. Until recently, the electricity industry has been fairly stable as well, but could now be on the brink of a disruptive change with the emergence of the smart grid technology. The smart grid is not a technology that has emerged in isolation, but it is closely integrated with a broader transition of the electricity industry towards sustainability. In the remainder of the paper we will analyze, therefore, to what extent smart grid technology seems to challenge the business models of incumbent electricity firms and under which conditions it could be considered as disruptive to the industry.

4. Smart grid challenges for the business model of electricity firms

4.1. The smart grid as a disruptive technology

The smart grid holds potential for being disruptive to electricity firms, as it could lead to fundamental changes in the structure of the electricity market. The two-sided flow of electricity and information would change the value chain of electricity generation, transmission, distribution, and supply. The interdependency between different actors of the network would increase, the distinction between the roles of suppliers and consumers would blur, and consumers would demand other sources of values than solely electricity. Thus, to survive in such a new environment, electricity firms might have to adjust their business model to stay abreast of the changing rules of game. However, smart grid demonstration projects show that electricity firms have not yet been actively developing innovative business models (Catalin et al., 2014; Mah et al., 2013).

In line with incumbents facing conscious and unconscious barriers to develop new business models (Amit and Zott, 2001; Chesbrough, 2010; Sosna et al., 2010), electricity firms seem to hesitate with developing innovative business models to deal with smart grid technology. That is, they might have decided not to innovate their business models out of fear of losing revenues, as long as they still profit from their established business model based on scale economies. Uncertainty about whether a novel business model built around smart grid technology would be equally profitable could inhibit experimentation with new business models. As we will discuss in the following sections, how electricity incumbents perceive this uncertainty will be central to their investment decisions with regard to pursuing business model innovation with regard to smart grid technology. On the one hand, electricity firms might see their profitability threatened by smart grid technology and thus steer clear from it; on the other hand, if they manage to find a business model that allows them to tap into new sources of value, they might instead embrace the technology.

Hence, what seems pertinent for electricity firms to benefit from smart grid technology is to find a new business model, even if it goes against the "dominant logic" of the industry (Chesbrough and Rosenbloom, 2002; Chesbrough, 2010; Sabatier et al., 2012). A recent study of German electricity firms' reaction to the emergence of renewable energy suggests, though, that moving away from the dominant logic might be a challenge indeed (Richter, 2013). While consumers' increased use of distributed renewable energy is lowering electricity firms' revenues, they failed to renew their business models to cope with this change. Their main response to government support for renewables has been to substitute fossil-fuel-based power plants with large-scale renewable generation capacity. While the core technology for power generation changed, the firms left the main elements of their business model, e.g. the value proposition and revenue mechanisms, largely unchanged. It thus seems that these firms could not imagine a business model outside of the current logic of large-scale power generation to deal with distributed generation (Richter, 2013). The question is if the same holds true for smart grid technology. In the following sections, therefore, the consequences of smart grid deployment on the elements of electricity firms' business model, including value proposition (consumer perception and relationship), value creation and delivery (value network structure as well as resources and capabilities), and profit model (cost structure and revenue streams), will be discussed in more detail.

4.2. The smart grid and electricity firms' value proposition

4.2.1. How is consumers' value perception changing?

Over the last decade, socio-technical changes have led to the emergence of new needs among consumers, which challenge the traditional perception of the value electricity firms provide. The smart grid could form a catalyst for pushing electricity firms to act on these changes in consumer behavior, but only under specific conditions. That is, even though consumers might state changed preferences, whether they act on them is still debatable. This uncertainty about consumer behavior might have consequences for the extent to which smart grid technology will change electricity firms' value propositions.

The first behavioral trend that has emerged among consumers is environmental friendliness. Recently, governments across the world have implemented regulatory support schemes, such as feed-in tariffs, to encourage consumers and industries to limit fossil fuel consumption (Al-saleh and Mahroum, 2014; Wüstenhagen and Bilharz, 2006). Accordingly, concern for the environmental impact of energy consumption has increased (Richter, 2013). Smart grid deployment could stimulate consumer interest for renewable energy, because it facilitates integration of distributed energy into the grid (Clastres, 2011). Despite the fact that an increased uptake of renewable energy could endanger electricity firms' revenues, the need to present a "green image" could motivate them to invest in centralized renewable power plants or provide distributed generation capacity with support services (Richter, 2013). Still, given the evidence suggesting that regulatory support schemes are the most important driver for consumers buying green electricity (Wüstenhagen and Bilharz, 2006), in the absence of such support this behavioral trend might be rather marginal. Hence, a country's regulatory framework for green electricity could significantly influence the impact of the smart grid on electricity firms' value proposition in terms of whether they perceive cross-fertilization between the smart grid and renewable energy integration.

The second behavioral trend growing among consumers is a tendency to have more control over electricity consumption (Clastres, 2011). Rising electricity prices as well as increased use of electrical devices and appliances has left consumers with higher electricity bills. In a recent survey on energy-efficient behavior of households, 82% of the respondents showed concern about the costs of energy consumption and affirmed adoption of energy-efficiency measures with low investment costs (Mardookhy et al., 2014). The smart grid would increase consumers' ability to control electricity consumption. Smart meters equipped with visual displays enable consumers to have access to real-time electricity consumption data (Geelen et al., 2013; Römer et al., 2012; Valocchi et al., 2007). If consumers manage to control electricity consumption more effectively, the smart grid could thus threaten electricity firms' revenues. It has been argued, therefore, that the smart grid would push electricity firms to change their value offering from selling electricity as a commodity to providing energy efficiency as a service (Fox-Penner, 2010), and thus encourage sufficiency (Bocken et al., 2014). While consumer concern about energy usage might be rising, whether this will translate into an increased demand for such energy services is still uncertain though. Recent evidence shows that in most countries the market for energy services is only growing at a slow pace (Marino et al., 2011). Hence, whether a change from selling electricity to selling energy services will materialize, largely depends on the signals electricity firms receive about the maturity of the market for energy services.

The third behavioral trend influencing consumer expectations is the utilization of electric vehicles. The amount of electricity needed to charge the battery of an electric vehicle will have a significant impact on the total electricity consumption. Electric vehicles would pose extra load to the grid and increase the complexity of grid load management, especially if charging times overlap with the current peak hours of electricity usage (Carillo-Aparicio et al., 2013; Clastres, 2011; Lo Schiavo et al., 2013). Building an adequate number of recharging stations and supplying them with sufficient electricity load could thus be among the value propositions of electricity firms in the near future (Carillo-Aparicio et al., 2013; Lo Schiavo et al., 2013). As with renewable energy, though, the uptake of electric vehicles is still largely policy-driven (Sierzchula et al., 2014). Hence, electricity firms will probably only feel the need to supply a recharging infrastructure as part of their value proposition, if there is sufficient government support for electric vehicles in the markets they operate.

Finally, demand for a higher quality of electricity supply and less power outages is growing among consumers. In the presence of a smart grid, the number of entities plugged into the grid and the interdependency between them will increase (Zio and Aven, 2011). Similar to transportation, the activities of other sectors will increasingly rely on the electricity supply. Therefore, keeping the quality of the electricity supply on an acceptable level and preventing power outages will be crucial. The communication infrastructure of the smart grid would enable electricity firms to detect problems in the state of the grid in advance and treat it immediately with the help of various distributed sources of power supply (Clastres, 2011). Whether electricity firms will consider the quality of supply as an integral part of their value proposition will depend on their level of vertical integration though. The liberalization of

European electricity market has led to a process of unbundling transmission and distribution from generation and supply (Jamasb and Pollitt, 2005). Nevertheless, in many other markets electricity firms are still vertically integrated. A highly integrated structure means that firms are responsible for all parts of the electricity value chain, and will thus be more concerned about maintaining the quality of electricity supply. In case of more specialized firms, such as electricity retailers without generation capacity, improved balancing that smart grid technology could bring will probably not be important for their value proposition to consumers.

4.2.2. How the smart grid would affect consumers' relationship with their electricity supplier?

In the traditional electricity value chain, the one-way flow of electricity and information puts electricity firms in the position of power and control over consumers. However, smart grid deployment could create major changes in the consumer-electricity supplier relationship, as it might give consumers more bargaining power over electricity suppliers. This power derives from consumers having more control over electricity usage, more freedom to choose an electricity supplier, and the opportunity to trade with electricity firms (Geelen et al., 2013). The role of consumers in the value network would become particularly strong if they are a co-provider of electricity, referred to as "prosumer", using distributed energy such as solar panels. Consumer empowerment could thus be a threat for electricity firms' value propositions. Then again, smart grid technologies could also allow electricity firms to use consumer empowerment to their advantage, if they manage to let consumers participate in network optimization, known as "demand response" (Geelen et al., 2013). Electricity firms could benefit from an improved balancing between supply and demand, when the smart grid enables consumers to shift load from peak to off-peak times. While the smart grid allows firms to meet consumer needs to gain more insight into energy usage, only when such transparency leads to demand response, will the investments in the infrastructure be justified (Faruqui et al., 2010; He et al., 2013). Consumers' contribution to keeping the balance between demand and supply is therefore crucial for value creation from smart grid investments.

Not all consumers show the same level of participation in demand response though, as they also have concerns other than the impact of their electricity consumption on the grid's load balance. To make demand response an integral part of the value proposition, electricity firms should be able to overcome the barriers to consumer participation. They can provide consumers with innovative services to either persuade their active participation or receive their passive response (Boait et al., 2013; Clastres, 2011; Geelen et al., 2013; Giordano and Fulli, 2011; He et al., 2013). Various combinations of products and services – such as providing consumers with micro generators, real-time feedbacks (Gans et al., 2013), pricing signals (Faruqui et al., 2010; Mizobuchi and Takeuchi, 2013), energy-efficiency advice (Gangale et al., 2013), and energy monitoring and home controlling systems (Geelen et al., 2013; Giordano and Fulli, 2011) – have been proposed to generate demand response. The effectiveness of such services has been tested through surveys and experiments in several studies (Gangale et al., 2013; Geelen et al., 2013; He et al., 2013), showing that it varies among consumers and depends on several factors such as income, education level, culture and climatic conditions at the residential area. Therefore, whether making smart-grid-based solutions for balancing the grid an integral part of the value proposition will pay off, will depend on a good understanding of consumer preferences and their likelihood to actively engage in demand response.

4.3. Smart grid consequences for electricity firms' value creation and delivery elements

4.3.1. How would the smart grid affect electricity firms' structure of value network?

The traditional value chain of electricity starts from the generation of electricity in centralized power plants and ends in consumers' usage point. Smart grid deployment would create considerable changes in this value chain. The addition of new technologies to the grid would bring new players to the field and create new sources of value (Erlinghagen and Markard, 2012; Giordano and Fulli, 2011). While the smart grid might be an important source of value creation, potentially a more relevant question for electricity firms is around value capture. New players might help to create value, but they will also try to appropriate this value (Jacobides et al., 2006). As a consequence, electricity firms face the challenge to find a balance between cooperation and competition; in the early stages of technology development they can cooperate with new players, but in doing so they might help create their new competitors for the years to come (Pinkse and Kolk, 2010).

To identify the potential new players in the value chain and analyze their position vis-à-vis electricity firms, we used the European Commission Joint Research Centre's (JRC) annual report of smart grid projects (Giordano et al., 2013). In this report, Giordano and colleagues investigated the type of participants and their strength of collaboration in the smart grid demonstration projects across Europe. Their findings suggest that electricity firms have established strong collaborations with universities and research centers, manufacturers of new technologies and ICT firms. The strong presence of universities and research centers in the projects shows the novelty of knowledge and technologies of smart grid projects for electricity firms. Universities and research centers are mainly leading the R&D projects. Once the smart grid technologies pass their development phase and reach a relative standardization, the role of public research centers would probably be less strong.

ICT firms are also new actors in the electricity value chain. To compensate for their lack of ICT knowledge, electricity firms have started to partner with ICT incumbents and to acquire ICT start-ups (Erlinghagen and Markard, 2012). Technologically, the smart grid has been conceptualized as multi-layered, comprising a hardware-based physical layer and a software-based market layer (Giordano et al., 2013). Examining the smart grid demonstration projects shows that the hardware layer, including transmission and distribution equipment is supplied by incumbents of the electricity sector, while the provision of software and communication layers are dominated by ICT incumbents. Software developers such as SAP or Oracle supply the software layer and IT system integrators such as IBM or Atos serve the software layer (Erlinghagen and Markard, 2012; Giordano et al., 2013). In 2012, 60% of smart grid projects involved at least one ICT firm and 17 of them are even led by ICT firms (Giordano et al., 2013). These figures show the ambitious presence of ICT firms in smart grid projects, which could be due to the maturity of the ICT sector. The moderate growth rate of the ICT sector has made the other sectors such as electricity an attractive destination for ICT incumbents (Erlinghagen and Markard, 2012).

Although ICT firms are cooperating with electricity firms by complementing their hardware with software-based integration, there are signs that they may become competitors in the near future. As Erlinghagen and Markard (2012) found from analyzing their own database of smart grid projects, the role of electricity firms and ICT incumbents in current projects have some overlap, as they are competing on technology standards. Projects led by electricity firms, for example, tend to use Power Line Communication or Radio Frequency Mesh technologies, while projects led by ICT firms tend to be based on GSM and wired broadband technology. Which type of technology will become the standard is not yet clear. Notably, Erlinghagen and Markard (2012) also noticed that ICT firms have been taking the position of the general contractor in several smart grid projects and thus maneuver themselves in a more central position in the value chain.

Manufacturers of renewable energy technologies, storage devices, and electric vehicles have also started collaborating with electricity firms (Giordano et al., 2013). Renewable energy firms, who have already established several joint-venture and partnership agreements with electricity firms to develop large-scale renewable power plants (Richter, 2013), deliver technological solutions to integrate the distributed renewable energy with the grid (Giordano et al., 2013). Car manufacturers are another group of new entrants. Electric vehicles can act as distributed energy storage, enabling electricity firms to perform load shift (Inage, 2010). Using electric vehicles as a storage device will only be possible if car manufacturers invest in related recharging technologies. The partnership of Volkswagen and LichtBlick in Germany for home-based power plants is an example of car manufacturers starting to play a role in the electricity value chain (Klose et al., 2010).

Finally, a number of start-ups have emerged that have used ICT infrastructure to offer energy management solutions to electricity firms. Distributed renewable-energy sources and electric vehicles would create multiple directions of power flow in the grid which along with the unpredictable generation rate of renewable energy and charging pattern of electric vehicles would make grid management very complex. Helping electricity firms to overcome this complexity has triggered the establishment of several start-ups with various ranges of offerings. In the US, for instance, Silver Spring Networks have designed a smart energy platform which provides software and services with the aim of reducing electricity firms' costs. EnerNOC offers a full-service demand response management to electricity firms through which they assure them with a certain level of peak load reduction and accomplish all necessary tasks. While being complementary to electricity firms, such start-ups are creating a new competitive dynamics among each other in gaining market share.

To summarize, smart grid deployment would expand the diversity of electricity firms' partners and interactions. The industry architecture of the electricity sector will change considerably (Jacobides et al., 2006), raising the question if electricity firms still manage to be in a central position. Depending on their prospects to appropriate enough of the value created and not face too much competition from firms providing services that seem complementary at first, electricity firms are likely to decide in what way and to what extent they will engage in collaborative projects. In any case, managing the value network becomes more complex and will require specific skills that are not currently among electricity firms' core capabilities, such as marketing, customer relationship management, and integration skills (Valocchi et al., 2014).

4.3.2. How would the smart grid affect electricity firms' resources and capabilities?

A major issue when firms are confronted with a new technology that might disrupt their industry is whether they are still able to leverage their most important resources and capabilities (Lavie, 2006). If a change in the business model would change the dominant logic of the industry (Sabatier et al., 2012) and weaken the value of incumbents' resources and capabilities, resistance seems likely (Bohnsack et al., 2014). How the smart grid will affect electricity firms' resources and capabilities, and whether they will embrace or resist the technology, depends to a great extent on their organizational structure. As discussed, there is a big difference between those electricity firms that are vertically integrated, including transmission and distribution, and those that are unbundled, focusing on generation and supply to customers (Jamasb and Pollitt, 2005). Besides, among the unbundled electricity suppliers, there are those with their own generation capacity and those without and exclusively source their electricity in the wholesale market.

One of the main benefits of the smart grid for electricity firms is the optimization of operations (Clastres, 2011; IEA, 2011; Poudineh and Jamasb, 2013). For example, it enables improved monitoring of the grid, and is so doing, to help promote security and safety of grid operations through the prevention cyber-attacks and early detection of failures. Data gathered from the grid along with the analytical software would allow electricity firms to predict outages and take optimal decisions when facing a problem. It is even anticipated that the smart grid in its advanced phases can function as a self–healing grid which automatically resolves outages and minimizes blackout times (Clastres, 2011; IEA, 2011). Hence, the smart grid could strengthen electricity firms' resources and capabilities in grid optimization. However, such optimization will be important predominantly for vertically integrated firms that have the management of the transmission and/or distribution network among their core activities. For unbundled firms, improved grid management will be far less relevant, although not negligible as they are still part of the whole electricity value chain.

Besides, while smart grid deployment might change electricity firms' value proposition from selling electricity to selling energy efficiency and related services (Fox-Penner, 2010), the smart grid technology could facilitate firms to make such a transformation. That is, the smart grid could reinforce the marketing capabilities, as it allows getting access to real-time information of all the grid's entities and to distributed power sources. Electricity firms can track the consumption patterns of their consumers and gain accurate knowledge of their needs and preferences. They can use this information themselves to customize their offerings to consumers or sell it to other actors. However, as seen in the previous section, it is ambiguous if electricity firms have the skills to make sense of such 'big data' (Piccoli and Pigni, 2013); ICT firms seem better equipped. So while the smart grid could improve electricity firms' marketing capabilities, it remains to be seen if they can acquire the skills needed to use 'big data' to improve the relationship with their customers. It seems that those firms that focus on the retail-side of the value chain are most likely the ones to benefit more of this potential benefit than those with limited interaction with the final consumer.

The smart grid could disrupt the industry's dominant logic of selling electricity at the lowest cost possible based on scale economies and thus threaten the viability of the main resource of many electricity firms: centralized power generation. However, the fact that it enables the integration of distributed renewable energy sources, storage devices and electric vehicles to the grid would provide electricity firms with access to other sources of power generation besides large-scale fossil power plants. This would reduce electricity firms' operational costs and help them to create value for environmental-friendly consumers and comply with policy requirements (Lehr, 2013). Besides, such a move away from centralized power plants will improve the flexibility of electricity firms to change their strategy. It will be easier to make adjustments to the power mix and respond to regulatory requirements or competitors' strategic moves. So while the smart grid will at first have a better fit with the capabilities of firms focused on retailing, in due course it might also be relevant in facilitating the energy transition for firms that now still have centralized power generation. That is, the smart grid might be an important enabling technology for incumbents to tap into new revenue streams.

4.4. Smart grid consequences for electricity firms' profit model

4.4.1. Consequences of smart grid on electricity firms' revenue generation

Smart grid deployment would challenge electricity firms' traditional profit model. As reported by previous studies, uncertainty about the profitability of the smart grid has created resistance and hindered diffusion (Catalin et al., 2014; Clastres, 2011; Giordano and Fulli, 2011; Mah et al., 2013). Through empowering consumers, encouraging them to use of distributed renewable energy resources and providing them with more control over their consumption, smart grid deployment would lead to a drop in revenues from selling electricity (Adam, 2008; Klose et al., 2010). However, as explained above, other sorts of needs and values would appear on the consumer side that electricity firms could generate revenues from by addressing them. A key part of business model innovation would therefore be that electricity firms are able to generate revenues that are not related to selling electricity directly.

The first source of new revenue streams lies in the ‘big data’ that the smart grid produces. To engender demand response and make consumers more aware of their energy consumption, electricity firms can provide visual feedbacks on electricity consumption, based on daily or hourly intervals or provide ‘free’ devices and applications. In return, consumers would permit electricity firms to access their consumption data and demographic information, which could be used by electricity firms in several ways. First, they can use this information for optimization of the grid or to develop new value offerings themselves. If the received information from consumers would also include their type of usage, for instance heating, cooling or lighting, then electricity firms can come with a more radical innovation in their business model. They could charge consumers based on the type of usage not the amount of kWh of electricity (Fox-Penner, 2009). Different pricing schemes could also be proposed based on dynamic pricing, with different prices depending on the time of the day electricity is used (Faruqui et al., 2010).

Second, the data can be sold to application providers, device manufacturers and other interested actors to customize products based on consumers’ needs and preferences (Clastres, 2011; Valocchi et al., 2014). For example, energy service providers would have an interest in consumers’ electricity usage to provide consumers with energy efficiency tips and notifications, home auditing and repair, and other consulting services. However, the data could also be of interest to firms that are unrelated to electricity but would like to get a better insight into consumer behavior, more generally. Hence, the electricity firm would be the aggregator of the consumer information, and generate revenues by selling the information (Valocchi et al., 2014). Whether enough other firms would be interested in this type of big data remains to be seen, but the rapid developments in related fields such as social networks, streaming services and online shops seems to indicate that it could be a sizable market (Piccoli and Pigni, 2013).

The second source of new revenue streams lies in selling new services. For example, electricity firms can also help consumers to buy energy-efficient appliances or replace their old energy consuming ones with new and efficient ones. As an example, Duke Energy, an electricity firm in the US, offers consumers energy-efficient bulbs for free and established an appliance recycling program through which it buys old appliances of consumers. Through long-term contracts with appliance manufacturers, electricity firms can provide discounts or installment payments for consumers, especially cost-sensitive ones. To keep the complexity of dynamic pricing away from consumers, electricity firms could also implement automation services such as home energy management systems or smart appliances (Geelen et al., 2013; Giordano and Fulli, 2011). They can offer dynamic pricing with the smart home technologies as a bundle to consumers and manage the operation of appliances from a distance (Cappers et al., 2012). Besides, electricity firms can help consumers in managing their own distributed renewable energy generation, such as services to improve the efficiency or to facilitate the maintenance of the generator equipment (Richter, 2013; Valocchi et al., 2007). They can offer packages of equipment, installation, advices and maintenance services with competitive prices or even for free, and guarantee to feed-in the excess of electricity produced.

As with the big data, electricity firms face the question whether to develop energy services for their customers on an exclusive basis themselves, or to open up the grid to third-party service providers (Giordano and Fulli, 2011). They need not be the ones providing the services directly to their customers, they can also generate revenues by allowing third-party providers access to their customers. In other words, the smart grid can create a so-called multi-sided market or platform (Giordano and Fulli, 2011; Valocchi et al., 2014), which consists of multiple suppliers on one side, and multiple customers on the other (Eisenmann et al., 2006). The advantage of a multi-sided market is that it allows electricity firms to leverage resources and capabilities of other firms, for example of those specialized in energy services or software applications. Electricity firms are in a good position to profit from owning and/or controlling such a multi-sided market, because they already have a vast customer base and relationships with suppliers and intermediaries in the electricity value chain (Valocchi et al., 2014). A multi-sided market will be more successful the more service providers and customers use it on both sides, because it will increase the fees charged by the electricity firm to get access to the multi-sided smart grid. Like a social network, though, the uncertainty for firms lies therein that they need to have a critical mass of 'users' on both sides for it to be profitable, otherwise it results in waiting games (Clastres, 2011; Eisenmann et al., 2006).

4.4.2. Consequences of the smart grid on electricity firms' cost structure

Finally, since smart grid deployment would involve adding a new infrastructure to the current electricity network, it would impose investment and operational costs on electricity firms. At the same time, it would allow electricity firms to avoid spending in other areas. Investment costs mainly consists of smart meters, communication facilities, controllers, software and other IT components added to the grid, as well as "sunk costs of previously installed traditional meters" (Giordano et al., 2012, p.28). Besides investments, electricity firms would face maintenance costs of added infrastructure such as smart meters, and operational costs of the new tasks such as the costs of "communication/data transfer", new "customer engagement programs" and costs of training existing personnel or recruiting new people (Giordano et al., 2012, p.30).

However, the effects of the smart grid on electricity firms' cost structure do not just add up. In fact, the smart grid would eliminate several types of expenses from electricity firms' operations, which in the long term would compensate for upfront investments. ICT infrastructure of the smart grid can be used to reduce the maintenance cost of the grid infrastructure. Through enabling constant and remote control of the grid physical components, the need for sending crew for site visits would considerably decrease; detection of equipment's failures would accelerate and efficiency of maintenance works would improve (Giordano et al., 2012). The same would happen for most of operational tasks, such as meter reading. Since smart meters' data can be collected and communicated to electricity firms automatically, there would be no need for assigning human resources and logistics to read meters. Not only would the cost of meter reading reduce considerably, but also the possibility of electricity theft would diminish (Faruqui et al., 2010).

In addition, installation of smart meters and home management systems might give rise to peak hours' load-shift by consumers which will result in considerable avoided costs of peak generation capacity. Faruqui et al. (2010) estimated that the benefits of load-shift can compensate for 20% to 50 % of investment costs in case of smart meter installation. Consumer participation in load-shift, along with the integration of renewable energy sources, storage devices and electric vehicles to the grid would reduce the need for power generation in fossil fuel power plants (Battaglini et al., 2009; Poudineh and Jamasb, 2013). Moreover, since the distributed generators are close to the consumption point, the need for investment in the transmission infrastructure would be minimal (Poudineh and Jamasb, 2013). On the other hand, instability of fossil fuel prices (Richter, 2013), increasing carbon taxes, and high costs of maintenance and repair of old fossil power plants have caused the operation costs of power generation from fossil power plants to increase (Lehr, 2013). Therefore, lowering their generation rate and using distributed renewable energy resources to supply the rest of demand could be beneficiary in the long term.

To conclude, since the smart grid projects have essentially not yet moved beyond the demonstration phase, an accurate calculation of revenues and costs is not yet possible; only potential sources and rough estimates can be predicted. While it has been argued that the smart grid's enabling of distributed generation might reduce revenues from selling electricity (Adam, 2008; Klose et al., 2010), there is no evidence yet that clearly shows that this will indeed be the case. As the epigraph at the start of his paper showed, Germany seems the first country where such a change might be taking place, but the reasons for this to happen are far more complex. Smart grid deployment does not seem to be the driver behind this transition, although it might be an important catalyst. Likewise, how the costs structure will be affected depends greatly on the specific country context as well, as many governments are likely to support the roll-out of the advanced metering infrastructure (McHenry, 2013), which forms a fundamental component of the smart grid. Some upfront investments might therefore not end up on firms' balance sheets, which would change their decision-making on whether to support smart grid deployment or not.

5. Conclusion

The main aim of this paper was to create insight into the consequences of smart grid deployment for the existing business model of established electricity firms. Based on a critical review of the emergent literature about the smart grid, we sought to explain under which conditions smart grid deployment has an enabling and/or constraining effect on sustainable business model innovation in the electricity sector. So far, the literature has predominantly highlighted the enabling effect of the smart grid on business model innovation in the electricity sector (Fox-Penner, 2010; Giordano and Fulli, 2011; Valocchi et al., 2014); for example, it would help electricity firms to move from a model based on selling electricity to selling services, it would facilitate the growth of distributed renewable energy as well as electric vehicles, and it would allow consumers to have a more active role in the electricity market. What we tried to shed light on as well, though, is that the potential constraining effect. That is, incumbents in the electricity sector have many reasons not to embrace the smart grid and hesitate to change their business model to accommodate smart grid technology and make a turn towards sustainability (Boons and Lüdeke-Freund, 2013). While electricity firms want to benefit from what smart grid technology brings, they seem less enthusiastic about allowing it to disrupt the dominant business model in the sector (Sabatier et al., 2012).

We identified several conditions that influence whether smart grid technology will be an enabling or constraining factor for electricity firms' business model innovation. First of all, what seems crucial is an active role of consumers. The attractiveness of the smart grid is in empowering consumers via demand response and renewable, distributed energy generation. While changing consumer preferences towards more environmentally friendly behavior and a need to control energy consumption might be necessary conditions, doubts can be raised about whether changing preferences will be sufficient for new value propositions of electricity firms to succeed. Electricity firms are seeking feedback from the market that new segments such as energy services are becoming more mature (Jacobsson and Bergek, 2004). Besides, it seems that only when governments put the incentives in place to motivate consumers to take on a more active role that their empowerment will materialize. Hence, adequate government support is another condition for electricity firms to engage in sustainable business model innovation, not only for smart grid technologies directly, but also for the wider energy transition. While government policy for the roll-out of an advanced metering infrastructure helps covering upfront investment costs, for example, policies to stimulate green electricity and electric vehicle adoption seem just as important as they influence consumer behavior.

In addition, the nature of their existing resources and capabilities forms an important condition for electricity firms to engage in business model innovation. Since the smart grid will change the value network of the electricity sector with new players entering the field, the question is whether incumbent firms are able to maintain their central position. Important determinants of existing resources and capabilities are the degree of vertical integration as well as the type of generation capacity they own. Vertically integrated electricity firms have more to gain, for example, from the improved balancing that the smart grid has to offer, as it helps managing the transmission and distribution parts of the organization. Then again, firms that have been unbundled due to liberalization policies might benefit more from the increase in information about energy usage to improve their marketing activities. Firms' ownership of fossil-fuel-based power plants will be an important boundary condition as well, because it could create a barrier against moving away from centralized power generation. Firms without their own generation capacity are more flexible to follow new directions and can experiment more easily with new value propositions. Besides, there is the issue of how skilled electricity firms are in managing and renewing their existing resource portfolio. That is, are they able to change their resources and capabilities themselves or to cooperate with other firms to gain access to complementary assets needed to change their business model? The willingness of key decision-makers in electricity firms to make bold decisions with regard to reconfiguring resources and capabilities is a significant factor for business model innovation (Lavie, 2006; Teece, 2007). An underlying issue will be whether it is wise to cooperate with new entrants such as ICT firms, when there is the risk that doing so might provide these new entrants with a strategic position in the electricity sector in due course.

It is clear that there are still many unresolved issues with regard to the impact of the smart grid on electricity firms' business models. Based on our analysis we see a few directions for future research. With regard to the value proposition, it is worth investigating to what extent electricity firms are experimenting with new offerings and what the nature is of these offerings. It remains to be seen if they have a preference for developing new value offerings or rather improve the efficiency of their operations using smart grid technologies?

Besides, there is the question how electricity firms engage in sustainable business model innovation. Do they change their core value proposition or set up new business units focusing on the new type of business? Conceptually, this touches upon the long debate about ambidexterity and how firms can organize and balance the tension between exploration and exploitation (Raisch and Birkinshaw, 2008).

Regarding the structure of the value network, it would be interesting to investigate, which type of firm seems most active in developing the smart grid technologies, and why. Using patent analysis, the level of activity of different types of firms could be investigated. For example, while it has been argued that ICT firms will become more important players in the electricity sector, there is still limited evidence on the extent to which they do so (Erlinghagen and Markard, 2012). As to developing resources and capabilities, lots of ambiguities remain on how electricity firms are developing or acquiring the capabilities needed to be competitive in a smart grid context. Do they prefer for internal development to safeguard their central position or would they rather opt for alliances to obtain complementary assets from firms with specialized expertise? Also, electricity firms' reflection on these decisions may be different based on their characteristics such as their size, degree of vertical integration, or the main countries in which they operate.

Finally with regard to the profit model, a relevant question would be how electricity firms perceive the new revenue streams in the smart grid. While there is large emphasis on the opportunities provided by access to real-time information about activity in the grid, there is not much evidence how such information is used by electricity firms. While big data holds lots of promise for new revenue streams, how this market for information will develop is still uncertain. Since the smart grid is still under development, there are many questions in need of urgent answers, particularly so, because ongoing uncertainty about crucial issues such as how to tap into new revenue streams with the smart grid will lead to waiting games (Clastres, 2011).

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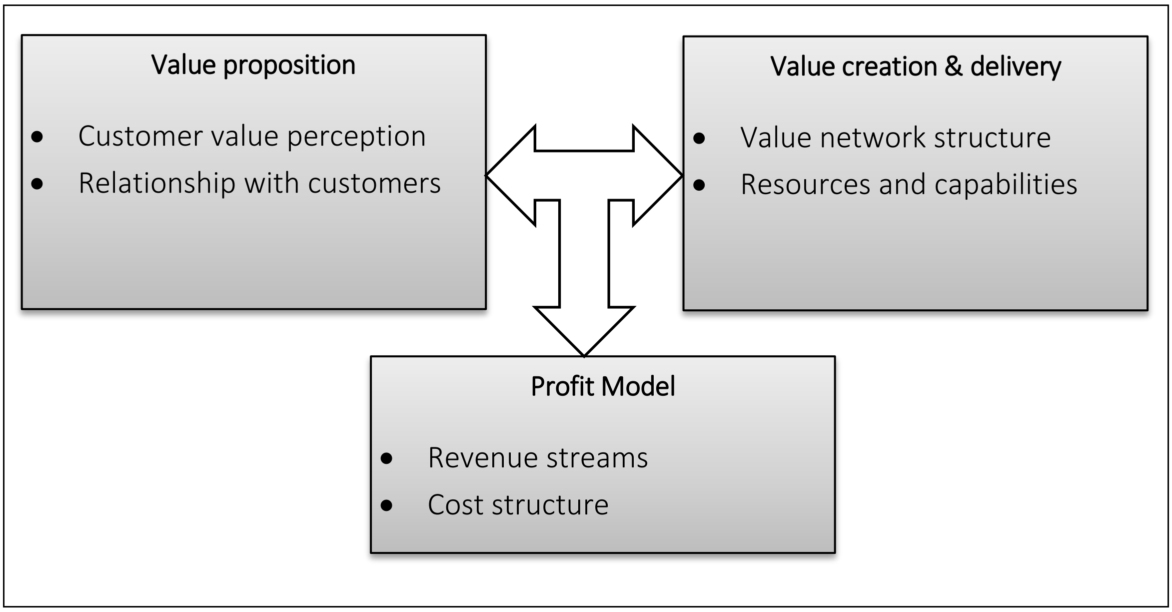

Figure 1: Business model framework used to understand the impact of the smart grid