

Buchmann, Marius

**Working Paper**

Information management in smart grids: Who should govern information management to balance between coordination and competition on the distribution grid level?

Bremen Energy Working Papers, No. 22

**Provided in Cooperation with:**

Constructor University Bremen, Bremen Energy Research (BER)

*Suggested Citation:* Buchmann, Marius (2016) : Information management in smart grids: Who should govern information management to balance between coordination and competition on the distribution grid level?, Bremen Energy Working Papers, No. 22, Jacobs University Bremen, Bremen Energy Research (BER), Bremen

This Version is available at:

<https://hdl.handle.net/10419/162176>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*



Paperseries No. 22

Marius Buchmann

## Information management in smart grids

Who should govern information management to balance between coordination and competition on the distribution grid level?

March 2016



JACOBS  
UNIVERSITY

**Editors:**

Prof. Dr. Gert Brunekreeft

Dr. Roland Meyer

Jacobs University Bremen

Bremen Energy Research (BER)

Campus Ring 1 / South Hall

28759 Bremen

[www.jacobs-university.de/](http://www.jacobs-university.de/)

<http://b-e-r.user.jacobs-university.de/>

**Contact:**

Dr. Roland Meyer

Tel. +49 (0) 421 – 200–4868

E-mail [ro.meyer@jacobs-university.de](mailto:ro.meyer@jacobs-university.de)

**Suggested citing:**

Buchmann, M., 2015, "Information management in smart grids. Who should govern information management to balance between coordination and competition on the distribution grid level?", Bremen Energy Working Papers No. 22, Jacobs University Bremen.

The "Bremen Energy Working Papers" are published by Jacobs University Bremen. The papers feature research and scholarship of a preliminary nature that should encourage dialogue and critical discussion. The content does not necessarily reflect the views of Jacobs University Bremen and is the sole responsibility of the authors. Jacobs University Bremen does not bear any responsibility concerning the contents.

# Information management in smart grids

## Who should govern information management to balance between coordination and competition on the distribution grid level?

Marius Buchmann - Jacobs University Bremen - Bremen Energy Research

[m.buchmann@jacobs-university.de](mailto:m.buchmann@jacobs-university.de)

1<sup>st</sup> draft

March 10, 2016

### Abstract

Smart grids should increase coordination on the distribution grid level and facilitate new market opportunities (I.e. competition on a level playing field). Information management is becoming a new task in the electricity supply chain. It is an enabler for the development of smart grids. Therefore, the governance of information management should as well efficiently balance between coordination and competition. Within this paper we analyse which role from the energy sector could govern the information management system. We conclude that neither of identified roles within the energy sector governing information management could secure both coordination and competition, at the same time. Therefore, new governance approaches (or new roles) are required.

*Keywords: Smart Grid, Information Management, Governance, Coordination*

## 1 Introduction

To reduce the costs of the integration of renewable generation into the distribution grids the exchange of data about demand, supply and potential flexibilities needs to be organized in a neutral and non-discriminatory way. This insight is derived from the current discussions in Germany about the costs related to the energy transition. Among others, a key driver for these costs are the distribution networks. Significant investments are required for these networks to secure the integration of renewable energies within the next decades. However, network expansion is costly. Alternative approaches that secure the integration of renewables into the distribution grid are based on information and communication technologies (ICT). These ICT-

based approaches are discussed under the headline of smart grids. Though there are various definitions for smart grids, it is the definition of the European Technology Platform for Electricity Networks of the Future (ETP SmartGrids) of the European Commission which underlies the current scientific discussion. It states:

”A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both - in order to efficiently deliver sustainable, economic and secure electricity supplies. A Smart Grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies [...]” (ETPSG, 2010, p. 6)

The concept of smart grids is applied to the distribution grids, i.e. the low-and medium- and high-voltage grids<sup>1</sup>. dena (2013) calculated for Germany that smart applications based on ICT could reduce network investments on the distribution grid level till 2032 by 45%<sup>2</sup>. Similar results were developed by E-Bridge et al. (2014). They calculated that the total costs for distribution network expansion in Germany could be reduced by 60%.

The results of these studies illustrate that the implementation of ICT in the distribution grids can secure the integration of RES at lower costs than traditional network expansion. Our analysis focuses on two important effects of smart grids: First, smart grids should increase coordination between the network operator and the network user. Thereby, investments in the network should be avoided as long as there is a cheaper alternative, e.g. load shifting. Second, smart grids are supposed to facilitate new business opportunities for market parties. I.e. it is expected that smart grids will increase competition in the electricity sector.

With an increasing share of ICT in the distribution grids the amount of data exchanged to operate the system increases as well. At the same time, more parties become active in the data exchange, e.g. distributed generation owners, storage providers or consumer participating in demand side management programs etc. These parties might be incumbents from the energy sector, but new market entrants as well.<sup>3</sup> The data exchange between the participants in smart

---

<sup>1</sup> in Germany distribution grids are defined as the networks up to 110kV, transmission networks operate at 230 kV or 400 kV

<sup>2</sup> This number does not include the costs for the operation and maintenance of additional components in the distribution grids. Therefore, the cost reduction potential will in total be lower than 45% but still significant

<sup>3</sup> These new market parties can be defined as third parties. A detailed analysis of the increasing role of third parties in smart grids was developed by Brunekreeft et al. (2015)

grids, i.e. the data handling, is becoming a new and important step in the electricity supply chain. From an institutional perspective the primary task of data handling is to secure that all eligible parties have the same access to the same data, i.e. data handling needs to secure a level playing field. The question then becomes, who should become responsible for this task? We address this question in the following chapters.

We acknowledge that several aspects need to be addressed in this context, from sustainability issues, to privacy concerns and IT operations. Our analysis focuses on an economic evaluation from a new institutional perspective and on the question which party should become responsible for the operation of the information management system. The paper is structured as follows: In section 2 we pick up the current discussion on data handling and define information management in smart grids. Section 3 specifies the institutional environment of information management in the energy sector. Here, we will introduce the liberalization process that took place in the energy sector to define the different roles that could become responsible for the information management in smart grids. Section 4 discusses resulting governance approaches for information management based on the identified roles. Specifically, we discuss three cases:

1. Information management as a monopoly provided by an established or new party in the energy sector
2. Information management as a task of the (distribution) network operators: For the network operators we discuss two options; either information management as part of the regulated business (i.e. an integrated task) or in the responsibility of the network operator, but separated from the regulated business, e.g. via firewalls as we know them from the unbundling process.
3. Information management as a new service provided by the market, i.e. the actors (incumbents or third parties) from the competitive parts of the energy system (generation, retail) could become responsible for information management

For these three cases we will discuss how they affect the coordination process between the distribution system operator (DSO) and network users in smart grids. We show that from a transaction cost perspective the case that the DSO integrates the information management into his regulated business seems favorable. However, this might result in incentives for the DSO

to discriminate non-associated market parties. Here we identify a tradeoff between coordination and competition. To address this tradeoff Ruester et al. (2013) propose further unbundling of the DSOs. We will pick up this proposal and discuss potential shortcomings of such a governance approach for information management. Section 5 concludes that neither of the identified roles in the energy sector could govern information management and at the same time balance between coordination and competition.

## **2 The current discussion on data handling from smart metering and the definition of information management in smart grids**

The research about the governance of information management is evolving from the discussions about the smart meter rollout in Europe. The European Union requires each member state to rollout smart meters to at least 80% of all costumers, if a cost-benefit analysis reveals the economic potential of this rollout (EUCOM, 2009). In Europe, only Sweden and Italy have finalized the rollout so far. Sixteen other member states are planning to rollout till 2020, though the targets for the rollout differ between 80% till 15% (CEER, 2013a).

Basically, two concepts are discussed to govern the smart meter rollout: a regulated approach, with the DSO being responsible for the rollout and a competitive (i.e. unbundled) approach, which leaves the rollout to the market. Haney et al. (2009) present a summary of the analysis of the two institutional designs for the smart meter rollout. They conclude that the institutional design can have a significant effect on the cost-benefit analysis and the distribution of benefits. While most European states introduced a regulated model where the smart meter rollout is an integrated task of the network operators (e.g. in the Netherlands), some have established an unbundled solution with a competitive metering market (e.g. UK and Germany have unbundled solutions that differ significantly from each other) (Wissner & Growitsch, 2010).

Similar to the debate about the smart meter rollout a discussion evolves about different models concerning the handling of data from smart meters. The EU Commissions Task Force Smart Grids proposes two regulated and one market based concept for data handling (SGTF, 2013). The regulated models delegate the responsibility for data handling either to the DSO or to a new regulated third party. The competitive approach is based on standardized market roles. Both the regulated and the market based approaches are supposed to secure neutral and non-discriminatory data management to establish a level playing field in smart grids. Ruester et al.

(2013) investigated in greater detail how the regulated concept with the DSO being responsible for the data management fits into the current institutional framework. From their point of view a further unbundling of DSOs is required to secure non-discriminatory data management (Ruester et al., 2013).

The discussion about the data exchange in smart grids has its roots in the debate of the smart meter rollout. Due to this fact, the term data handling was applied to summarize the ICT-related processes to transport the data from the provider (smart meter) to the recipient. However, the term data handling falls short to include relevant aspects within the discussion. Data in smart grids not only needs to be allocated, but stored, aggregated and verified as well. The discussion therefore does not only describe the physical flow of data, but needs to address the management of the data exchange as well, i.e. who should become responsible for this task, the ICT-system design and the required infrastructure. This broader perspective on the design of the data exchange in smart grids can be summarized under the concept of information management.

According to Voß & Gutenschwager (2001) information management is the economic efficient planing, purchasing, processing, distribution and allocation of information as a resource for the preparation and support of decision making processes. As well, information management implies the design of the required framework to efficiently process these tasks. By applying the information management concept to the data exchange in smart grids we follow Jagstaidt et al. (2011), who specified the concept of smart meter information management system from an ICT perspective. They use the Smart Grid Architecture Model (CEN-CENELEC-ETSI 2012) and define information management as the intermediary between the different actors in the energy system and the physical layer, which consists of the electricity and ICT infrastructure. Based on this perspective Jagstaidt et al. (2011) specifies the required processes within the information management system to support the data exchange from smart metering.<sup>4</sup>

Information management in smart grids is a new task in the energy system. So far the exchange of data was limited to the bilateral data exchange between two parties, e.g. in the

---

<sup>4</sup>Jagstaidt (2014) adds further detail to this discussion and specifies for different use cases which data needs to be exchanged between different agents in a smart grid.



process of supplier switching. Several questions evolve in the context of this new task. From an institutional perspective it becomes especially relevant to define who should become responsible for the new task of information management. Different governance approaches could be applied to define this responsibility. We put special emphasis on the institutional environment in the electricity sector that defines the different roles that could become responsible for information management. We briefly describe this institutional environment in the next section. Afterwards, we will address the different governance approaches for information management based on the identified roles (chapter 4).

### **3 The institutional environment of information management in smart grids - status quo**

The institutional environment of smart grids is mainly characterized by regulation and the results of the liberalization process in the energy sector. Joskow (1996) points out that the electricity sector went through a significant change within the last decades. Prior to the liberalization a hierarchical system existed in the electricity sector. Integration was mainly motivated by the gains from vertical and horizontal coordination within the utilities, which operated the monopolistic networks (national and transnational transmission networks and local distribution networks).<sup>5</sup> Thereby, the network monopolies served as a basis for the expansion into the other stages of the electricity supply chain. While this market structure was generally supported in the scientific discussion, the analysis of Joskow & Schmalensee (1983) specified the efficiency potential that could be realized through introducing competition in generation, i.e. unbundling of the network monopolies. Though the arguments for the introduction of competition were manifold, Joskow & Schmalensee (1983) stress the complexity of required coordination mechanisms (i.e. contractual relations) to substitute formally internal planning processes of integrated utilities. In the given context these contractual relations can be characterized as information exchange between the different stages of the electricity supply chain.

---

<sup>5</sup> Transmission (high voltage) networks are operated by one or a few Transmission System Operator (TSO) per country. The distribution (medium and low voltage) networks connect the endusers to the electricity network and are more fragmented in many European states (Germany has more than 900 distribution network operators).

The main argument against separation of the network from the other parts of the electricity supply chain is based on transaction costs. The exchange of information within an integrated utility can be more efficient than the information exchange between separated companies, as long as the market has not established efficient coordination mechanisms as well. With separation coordination of the competitive parts of the supply chain and the networks becomes especially relevant for investment decisions into the network infrastructure. Here, a coordination problem evolves due to missing information exchange between the generation companies and network operators (see (Brunekreeft & Meyer, 2009) or (Brunekreeft, 2015) for details). However, an efficient market based coordination mechanism could solve the coordination problem. Brunekreeft & Friedrichsen (2010) analyzed different market based coordination mechanisms in this context. Their analysis revealed that at least some instruments, e.g. locational pricing, could establish an efficient market based coordination mechanism (Brunekreeft & Friedrichsen, 2010)<sup>6</sup>.

Following up on the evolving discussion in the late 90s about cost and benefits of vertical separation the European governments came to the conclusion that for the transmission level the coordination gains from integration did not compensate for the losses from missing competition (EUCOM 2007). This is the root of the unbundling discussion, which primarily focused on the transmission level. We will shortly introduce this discussion, as it serves as a blue print of the current discussions about the institutional framework on the distribution grid level.

The liberalization process on the transmission level involved three steps, starting with the First Electricity Directive of 1996, which was followed by the Second Electricity Directive in 2003 and the Third Directive in 2009. The Commission pursued four goals by liberalizing the electricity market (for details see (Meyer, 2012)): The main goal of the liberalization process in the EU was to establish a single European electricity market. Second, liberalization was established to secure third party access to the markets in generation, trade and retail. Third, third-party-access to the network infrastructure was regulated to prevent discriminatory behavior by network owners against other generation companies. Fourth, final customers should be allowed to choose their electricity supplier.

---

<sup>6</sup> However, these instruments are not applied in Europe.

The current institutional framework is based on the 3rd legislative package of the EU. Thereby, the Commission introduced three different options for unbundling on the transmission level. The three options proposed by the 3rd legislative package were

- ownership unbundling
- the (deep) Independent System Operator (ISO)
- Independent Transmission Operator (ITO)

Full Ownership Unbundling prohibits joint ownership of network and generation or retail assets within one firm. The ITO model allows companies to retain both network ownership and management, but it puts strong limitations on cross involvement of employees to assure independence of the network. The ITO is in effect a stronger form of legal unbundling. The ISO requires that an independent entity takes over operational activities (system operation) in the network, separate from transmission asset ownership. With an ISO the network ownership can stay with the integrated firm, also owning generation assets.<sup>7</sup>

The regulations within the Third Electricity directive were motivated by the prior experiences with weaker forms of unbundling. Especially the experience with legal unbundling did not fulfill the expectations of the Commission. Legal unbundling was introduced in the Second Electricity Directive in 2003 and requires that the network operator is independent at least in terms of its legal form, organization and decision making from other activities not relating to transmission (i.e. generation and retail) (EUCOM, 2003). This includes unbundling of accounts, operations and information. The idea behind this is to ensure that no relevant information is exchanged between the network and other parts of the supply chain within one utility. One can think of legal unbundling as "firewalls" or "Chinese walls" which prohibit such a flow of information within one integrated company (Brunekreeft & Keller, 2001). Still, a legally unbundled network operator can be part of a holding company that owns generation and retail subsidiaries as well.

---

<sup>7</sup> The ISO model has been applied in several countries, e.g. UK, Ireland, Switzerland, the US and Canada (Pollitt, 2012). In Germany, the ITO model was applied. Here the transmission system is owned and operated by the ITO, which is legally independent from the vertically integrated company.<sup>77</sup> Though not legally required three out of the four TSOs in Germany have already applied ownership unbundling, while the fourth one is legally unbundled. The ITO model is applied in other countries as well, e.g. in France, Austria, Greece, Hungary etc. (Groebel, 2013).

Evaluating the outcomes of the unbundling process in 2007 the Commission concluded that legal unbundling did not sufficiently secure competition in the electricity sector. Therefore, the Commission concluded that

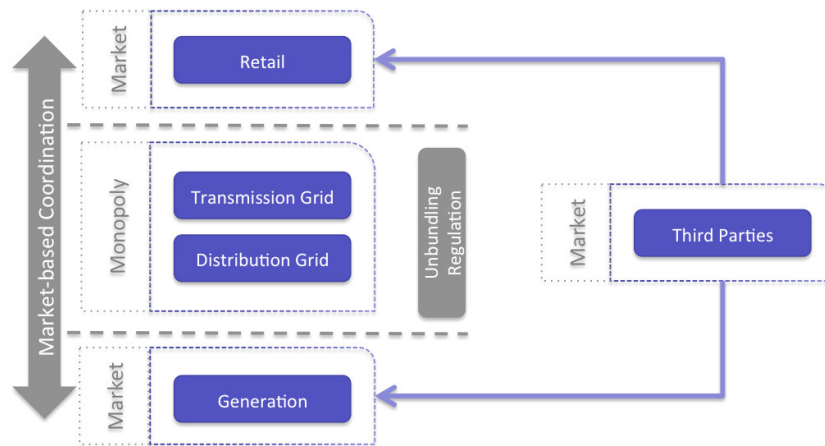
”[...]transmission ownership unbundling is the most effective tool to promote investments in infrastructure in a non-discriminatory way, fair access to the grid for new entrants and transparency in the market.” (EUCOM, 2007)

Importantly, the Commission focused strongly on the benefits of ownership unbundling, while the costs were neglected to some extent (Brunekreeft, 2015). Though the Commission was in favor of ownership unbundling on the transmission level it did not become mandatory in the EU. Rather, ownership unbundling became one out of three options within the Third Electricity Directive, due to the opposition of some member states. Today, the Commission seems to be rather satisfied with the achievements with the ITO model (EU COM 2014). Further unbundling on the TSO-level is therefore not an issue for now.

The institutional environment on the distribution grid level is different compared to the previously described framework on the transmission level. Distribution networks are currently subject to legal unbundling (EUCOM, 2009). However, legal unbundling is only applied for those DSOs that have more than 100,000 customers. DSOs with fewer costumers do not have to unbundle and can remain an integrated part of an utility. This exception is known as the de-minimis rule (specified in (EUCOM, 2009, Art.26)). Out of the roughly 880 DSOs in Germany only few (about 150) have such a large customer base, which in turn means that roughly 80% of all DSOs are still part of integrated utilities (EUCOM, 2011). It needs to be noted that the legally unbundled DSOs, which are not subject to the de-minimis rule, own large parts of the overall network in most member states of the EU. Typically, these larger DSOs own roughly 95% of the national markets (even though their number is quite low), exceptions are Denmark (43% market share of small DSOs) or Austria (12% market share in the hands of small DSOs) (Cossent et al., 2009).

Though a stronger unbundling regime was discussed in 2009 as well, it did not become mandatory in the EU. Still, some countries introduced ownership unbundling on the distribution grid level, for example the Netherlands. Even in countries where ownership unbundling is not mandatory, some DSOs are in fact fully unbundled from the electricity supply chain, e.g. in Belgium, Bulgaria and UK CEER (2013b).

Figure 1 summarizes the institutional environment of information management in the electricity sector.



**Figure 1:** *The different roles defined by the institutional environment of information management*

On a general level the institutional environment in the electricity sector defines 4 roles that could become responsible for information management. Either the regulated entities from the network monopolies, established incumbents from the generation or retail segment, third parties that are already active in the electricity sector or enter the electricity sector specifically to become responsible for information management. In the next chapter we pick up these roles and discuss different governance approaches that assign the responsibility for information management to either of them.

#### **4 The different governance models for information management: Can they secure a balance between coordination and competition?**

Information management could become a task of an actor that belongs to either of the four roles defined above. We can differentiate between three basic approaches to govern information management:

1. One institution from the 4 roles defined above could become responsible to govern the information management system for a specific region (e.g a whole country or one part of the country). This would result in a monopoly for information management.
2. The network operators could become responsible to operate the information management systems for their networks.

3. The roles from the competitive parts of the energy system (generation, retail) could become responsible for information management.

The first group of governance approaches focuses on a monopolistic structure. One institution from either of the four roles or a new party could become responsible to provide the information management system for a specific region. Importantly, information management itself does not qualify for a monopoly or a monopolistic bottleneck. This becomes clear when we take a look at the definition of monopolistic bottlenecks. Knieps (2006) defined two criteria, which define a monopolistic bottleneck:

1. "If the facility is necessary for reaching consumers, that is, if no second or third such facility exists, that is, if there is no *active* substitute available. This is the case if there is, due to economies of scale and economies of scope, a natural monopoly situation, so that one supplier can provide this facility at a lesser cost than several suppliers.
2. If at the same time the facility cannot be duplicated in an economically feasible way, that is, if no *potential* substitute is available. This is the case if the costs of the facility are irreversible" (Knieps, 2006, p.53).

Irreversibility describes an investment that cannot be recovered within a reasonable amount of time, i.e. the network can not be sold once it was built.<sup>8</sup> For new market entrants the existence and extent of irreversible costs determine whether or not they are willing to enter a market. In contrast, the incumbent player already incurred these irreversible costs. Therefore, the incumbent is no longer affected by these costs and has an incentive for strategic behavior, because the irreversible costs secure a certain state in which inefficiencies of the incumbent do not directly increase competition (Knieps & Zenhäuser, 2010)

Taking a closer look at information management reveals that there exist economies of scale, e.g. with respect to the storage capacities for the data exchanged in smart grids. Still, it is very likely that there are at least potential substitutes for information management. Though there is no specific data available that would help to prove this statement, the experiences with the market for storage capacities for private data, so called cloud-computing, might serve as an example for a similar market structure. Today, cloud-computing mainly consist of hardware, i.e. different servers which are connected to a network, and data or services which can be

---

<sup>8</sup> Irreversibility was analyzed in greater detail with respect to decisions, see Henry (1974)

accessed via these servers from every internet connection (Markovic et al., 2013). Though this market is still in its introduction phase, it is anticipated that there is a huge potential for economies of scale (Pal & Hui, 2013).

The current market for cloud storages is quite small. Nevertheless, there already exists competition between different IT companies, e.g. Google, Amazon, Microsoft etc. The services provided by cloud-computing and information management are at least partially based on comparable systems. Both require large data storage facilities that can be accessed externally from eligible service providers and costumers. Furthermore, cloud-computing as well as information management require huge data transfers from the costumer to the storage provider. Therefore, it seems likely that the developments within the cloud-computing market might serve as a first approximation for potential developments of information management in smart grids.

Taking the developments in the cloud-computing sector into account reveals that though economies of scale might exist, potential substitutes for the provision of information management in smart grids are likely to evolve. Therefore, information management does not qualify as a monopolistic bottleneck and it does not seem necessary to establish a monopolistic governance approach for information management.

Independent from the evaluations above information management could become an institutional monopolistic bottleneck. This requires that a governmental decision defines that there is only one information management operator available in a specific region. This region might cover a whole nation or just a part of a country. This governmental decision would then de-facto eliminate potential substitutes. Therefore, such institutional monopolies are also known as governmental-granted monopolies. In the UK the government assigned the responsibility for data collection and processing to an independent service provider (DECC, 2013).<sup>9</sup> Following from such a jurisdiction information management becomes a local monopolistic bottleneck by law. This is true for all the roles identified in chapter 3.

---

<sup>9</sup> The CEER (2012) stressed that the central approach in the UK creates a new monopoly, while a market based approach might have been possible as well.

The second group of governance models delegates this task to the network operators that already operate monopolistic infrastructures. Here, we differentiate between two concepts given that the network operators become responsible for information management. Either, information management is provided as an integrated task by the operator of the electric distribution (or transmission) networks. I.e. information management would become part of the regulated business of the network operator and would be subject to the respective regulation scheme of the network operator. Alternatively, information management could be a task of the network operators, but separated from network operation. This could be done by introducing firewalls between these two businesses (network operation and information management) within one company. The separation of network operation and information management would then require a process like ‘(legal) unbundling of information management’ to secure that the network operators do not misuse their market power on the network side to influence the information management business.

Given that the separation of information management from the regulated tasks of the network operators is effective, then the network operators could become active in a competitive market for information management where different parties from different roles compete with each other (e.g. some retailers compete with the network operators and third parties in the market for information management). However, several issues would need further specification to define how such a system with network and information management operators could look like.<sup>10</sup>

Third, all roles from the competitive realm (incumbents as well as third parties) could become responsible for information management. A market would exist where different providers of information management could compete.

Based on the previous evaluation two basic approaches to establish information management as a new task in the electricity supply chain can be differentiated. On the one hand, regulated

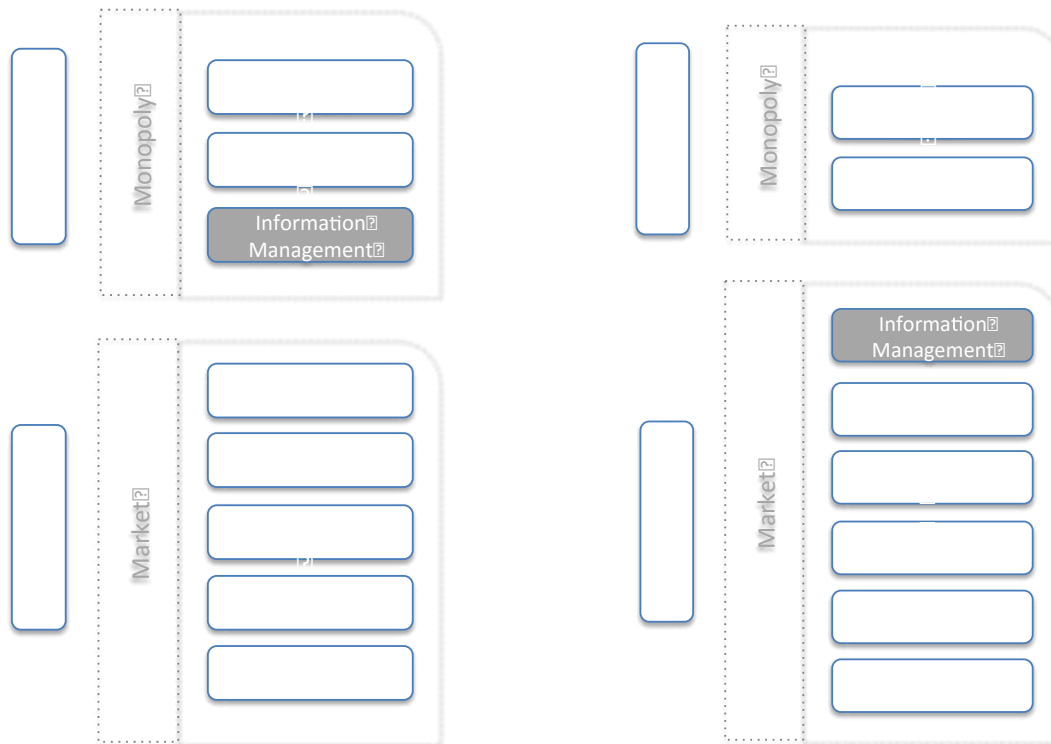
---

<sup>10</sup> Such an approach requires quite some effort to secure the separation of the regulated from the commercial business. The question then is: What are the gains from such a system that would justify the efforts to separate the regulated tasks from the information management? Furthermore, why should the firewalls that separate information management from network operation be more effective than the already existent firewalls of legal unbundling? Germany currently takes a step into this direction by unbundling (accounts and information) the metering operators from network operation. Some interesting insights might be derived from this process for the institutional design of information management.



concepts where information management either becomes an integrated task within the monopolistic elements of the electricity sector, i.e. the networks, or is operated as an institutional monopoly granted by the government. On the other hand, information management could become a separated task from network operation. Thereby, information management would be independent from the monopolistic infrastructure and belong to the competitive realm. In the competitive model any other party than the operators of the monopolistic bottlenecks could be responsible for this task. This includes incumbents from the electricity sector, as well as third parties (e.g. from the telecommunication sector), which are not yet active in both sectors. Alternatively, information management could be a task of the network operators as well, but separated by firewalls from the network operation. Theoretically, the network operator could then become active as a provider of information management in a competitive environment.

Given a separated solution (information management separated from the networks), the access to the electricity infrastructure would be regulated based on the established regulation schemes. Additionally, information management itself would be part of the competitive environment and therefore either subject to competition law or a regulation scheme independent from the monopolistic bottlenecks of the network industries. Though it is possible to think of competitive approaches for information management that do not require regulation (e.g. the DAM-concept of SGTF (2013)), regulation might still be needed if the separated solution results in an institutional monopoly (e.g. if there is only one data management system for a whole country like in the UK). The following figures illustrate both cases, the integrated and separated approach:



(a) Information management integrated within the regulated operation of the electricity networks

(b) Information management separated from the regulated operation of the electricity networks

**Figure 2:** *Information management as a separated or integrated task from/within the regulated operation of the electricity networks*

For both governance approaches we need to discuss how they relate to the existing institutional setup. Our analyses focuses on two specific criteria:

1. Coordination: Do the different governance approaches for information management have an effect on the coordination on the distribution grid level?
2. Incentives: Do the governance approaches secure that the relevant parties have the incentive to develop the information management system in an economic efficient way?

### **The governance of information management and coordination on the distribution grid level**

In the given context coordination describes the exchange of information within the electricity supply chain. Before liberalization this coordination was a hierarchical process, i.e. coordination took place within a utility that operated departments for retail, the networks and

generation within one company. After liberalization, the former integrated departments of the utilities were separated into different companies. Now the network company needs to coordinate externally with retailers and generation companies (Brunekreeft & Ehlers, 2006). Market based coordination mechanisms could substitute the former integrated coordination process. Potentially even at similar transaction costs. However, today the coordination between the network and the rest of the supply chain is weak. If at all, then this coordination is currently based on network charges, which are criticised to be imperfect (Brunekreeft, 2015).

Consider the case of an unbundled distribution system operator (DSO) and a generation company that wants to invest into distributed generation (DG) as an example. The DSO could implement locational differentiated network charges to give incentives to the investor to install the DG at a specific location where the installation of DG would not require investments into the network. However, this can only result in efficient outcomes if the network charges reflect all costs related to the installation of DG. Brunekreeft & Ehlers (2006) argue that shallow network charges, which is the most common model in Europe, do not reflect all these external effects from DG investments on the electricity network. Therefore, coordination based on shallow charges would result in an inefficient investment into DG (similar results were found by de Joode et al. (2009)).

Coordination is flawed between generation and network companies in further respects as well. While investment into DG might quite often require investments into networks as well, the investor in DG does not need to consider the DSOs plan for network expansion. Here, the missing exchange of information between DG and the network creates a coordination problem. More recently Niesten (2010) stressed that the coordination problem in the Netherlands already slows down the development of DG, which supports the argument raised by Brunekreeft & Ehlers (2006). With an increasing share of RES the coordination problem gains relevance in the current discussion (Ropenus et al., 2011; and Cossent et al., 2009).

In Germany it is currently discussed to introduce a mechanism to reduce the costs of the missing coordination between the network and distributed generation. The idea is to allow the network operators to curtail 3% of annual electricity production of the connected DG. The calculations of E-Bridge (2014) reveal a potential to reduce the network expansion costs by 30% when the curtailment approach is applied. The Federal Government is planning to

introduce a rule to allow the curtailment by the DSO within 2015. The necessity of the curtailment rule delivers proof for the existence of the coordination problem in Germany.

So far, the discussions about the coordination problem mainly focused on DG and the resulting network expansion costs. Presumably, coordination will become more complex with the introduction of smart grids. Complexity will be driven by at least two effects.

First, the number of stakeholders in the electricity system increases. These actors need to be coordinated to balance demand and supply. New stakeholders can evolve on the production side, as more DG is owned by small investors (even by households) or on the consumption side, where more consumers actively participate in the electricity system (e.g. based on demand response mechanisms).

Second, information in smart grids needs to be exchanged at a higher quantity as well as with a higher resolution. While grid operation might not need every data set per second of every customer connected to the grid, services on the market might have an interest in this detailed data and customers might demand these services. These new services are likely to have direct effects on the operation of the distribution grid. For example, demand response mechanisms aim at an adaptation of consumers demand according to price signals. So far, these price signals change over the day, but they do not take into account the balance of load and production on the distribution grid level. Today, the effect of these new services might be marginal as most of the instruments are only in the pilot phase. Nevertheless, a growing market for these services might significantly increase the coordination problem between the DSO and network users. Information management then needs to solve this problem efficiently, e.g. by reducing transaction costs.

The question then is: Can information management reduce these transaction costs between the network and the other parts of the supply chain, i.e. has information management a positive effect on the coordination problem on the distribution grid level? To answer this question we need to take into account two assumptions:

First, we can expect that the introduction of information management as a new task in the electricity supply chain will reduce transaction costs, independent from whether it is governed

as an integrated or separated task. This is due to the fact that the service offered by information management, the collection, aggregation, storage and distribution of data, itself will reduce transaction costs for the DSO. Especially the collection and aggregation of data offers potential for economies of scale and scope. Transaction costs will be reduced as the DSO does not need to contact each user of the network individually to gain information about current and anticipated grid usage, but can access this data at the information management provider. This might even be true if several different information management providers are active in the grid area of one DSO. However, with an increasing number of different information management providers in one network area the coordination gains from the introduction of information management might be reduced, as the DSO then again needs to exchange information with several different parties. Therefore, we argue that the introduction of information management, independent from its governance structure, offers the potential to reduce transaction costs.

Second, transaction costs for coordination between the DSO and the network users in smart grids are the lowest if the distribution network operator integrates the information management into its regulated business. In this situation the information management becomes one integrated department of the network operator. Therefore, the department for network operation can directly access the required data via the internal processes. However, this is only true for the case that information management is integrated into the hierarchy of the network operator and becomes part of the regulated business as well.

This changes if information management is a task of a separated department of the DSO, that is 'unbundled' from the network business via firewalls. If we suppose that these firewalls effectively separate the regulated activities of the network operator from its information management business, then transaction costs for coordination might not be lower than compared to a case with an external company providing the information management for the network operator. In both cases the network operator needs to contract with the information management company to access the relevant data.

To conclude, coordination becomes more important in smart grids and we see some evidence that an integrated approach that delegates the new task information management to the regulated network operators might reduce coordination costs.

### **The governance of information management: Do DSOs have the right incentives?**

The solution to integrate the information management into the regulated business of the network operator might reduce coordination costs, but it could result in inefficient incentives. Though information management would become a new task for the DSOs, the arguments against this solution are similar to those raised prior to the liberalization process. Back in the 90s, Joskow (1996) pointed at the risk that a regulated firm, which owns the network infrastructure and wants to be active in the competitive parts of the supply chain, might be able to discriminate against competitors or even restrict access of third parties to the system to increase own profits. In addition, a grid owner that takes part in the competitive sectors could be able to cross-subsidise its activities in the market through the regulated network tariffs in the natural monopoly part of its business. Newbery (1997) raised similar concerns with respect to integrated utilities that have the ability to control information and thereby discriminate other parties.

This criticism gains importance with the introduction of smart grids. Many benefits of smart grids are related to the innovation potential that comes from third parties (Erlinghagen & Markard, 2012). An integrated utility might therefore have the incentive to restrict access of third parties to the information in smart grids to protect its market share. If an integrated utility is responsible for information management, we can suppose that competition might be hampered. Within an unbundled world, these incentives to discriminate should be eliminated. Whether legally unbundling eliminates the incentives to discriminate sufficiently is still under discussion. Hoeffler & Kranz (2011) argued that legal unbundling might be the golden mean between integration and full ownership unbundling. However, Ruester et al. (2013) are skeptical whether legal unbundling efficiently eliminates incentives to discriminate. As far as the transmission system is concerned the European Commission seems to be satisfied with the effects of strong legal unbundling (EUCOM 2014).

On the contrary, a fully ownership unbundled DSO that is responsible for information management should have no incentive to discriminate. Though there are doubts whether ownership unbundling would be an efficient solution overall (see de Nooij & Baarsma (2009); Hoeffler & Kranz (2011); Brunekreeft (2014)), it could solve inefficient incentives to

discriminate and thereby might over a solution for information management in smart grids. This solution will be discussed in greater detail in the next subsection.

Compared to the integrated solutions the separation of information management from the monopolistic bottlenecks has the primary advantage that it reduces incentives to discriminate third parties. However, this is only true if the task of information management is assigned to a third party that is independent from all monopolistic bottlenecks and parties with market power.<sup>11</sup>

From the above we can extract two important implications for the governance of information management in smart grids. First, the coordination problem on the distribution grid level could be reduced if information management would be delegated to the electricity distribution network operators. Transaction costs could be reduced as well, if any other party than the DSO becomes responsible for the information management. Still, the effect of information management on the coordination problem is the stronger, if it is governed as an integrated task of the DSOs. Second, given the current institutional environment with legal unbundling of DSOs the integrated approaches that assign information management to the DSOs might result in incentives to discriminate third parties. In these cases regulatory oversight would be required to secure competition on a level playing field. Therefore, we face a tradeoff between coordination and competition: we can not secure both at the same time for information management given the current institutional environment.

It needs to be questioned whether a change in the institutional environment of smart grids could reduce the tradeoff between coordination and competition. Ruester et al. (2013) stress that the governance approach for information management based on an ownership unbundled DSO could result in an efficient balances between coordination and competition.<sup>12</sup> Based on the current regulation ownership unbundling is not mandatory in the EU. So far, mandatory ownership unbundling on the distribution grid level was so far only applied in New Zealand, where ownership unbundling of the distribution grid was introduced in 1998, and the

---

<sup>11</sup> This includes that the operator of the information management is not an affiliated company of either the same holding as a legally unbundled DSO.

<sup>12</sup> Though we focus on the relation between information management and ownership unbundling, we are fully aware that the discussion is much broader and complex.

Netherlands, where (most) DSOs are ownership unbundled since 2011.<sup>13</sup> The evaluation of Nillesen & Pollitt (2011) showed that in the case of New Zealand ownership unbundling had a positive effect on retail competition, but that this effect was limited to a short time period. Therefore, it might even be questioned whether ownership unbundling was the reason for this temporary increase in retail competition. There might have been other effects that influenced the retail market at that time as well. Nillesen & Pollitt (2011) conclude that ownership unbundling might not be considered as the primary solution to introduce competition in the electricity sector.

For the case of the Netherlands different cost-benefits analysis evaluated the effects of ownership unbundling on the distribution grid level, but come to different results. The analysis of SEO (2006) resulted in a welfare loss from ownership unbundling. These results are supported by de Nooij & Baarsma (2009). Based on these investigation it seems likely that the costs of ownership unbundling might exceed the benefits derived from it. Potentially, ownership unbundling on the distribution grid level might even result in decreasing competition given the case that generation and retail are still integrated, which could hinder independent retailers to enter the market (de Nooij & Baarsma, 2009). More recently, PWC (2013) evaluated the status quo of ownership unbundling in the Netherlands and concludes that so far the expectations were not met. On the contrary, the evaluations of Mulder et al. (2005) and Kuenneke & Fens (2007) revealed a potentially positive effect of ownership unbundling on the distribution grid level under certain circumstances.

The results from the described case study in New Zealand and some (but not all) of the cost-benefit analysis for the Netherlands support the decision in 2007 of the European Commission not to introduce ownership unbundling on the distribution grid level. Up to now, legal unbundling seemed to be sufficient to secure neutrality and non-discriminative access of third parties to the infrastructure.

Ruester et al. (2013) picked up the discussion about ownership unbundling in the context of information management. As information management is a new task in the electricity supply chain it might add some additional aspects to the cost-benefit analysis of ownership

---

<sup>13</sup> Though not required by law some DSOs in other countries like Belgium, Bulgaria, Romania, Portugal, Italy and UK are ownership unbundled as well (CEER, 2013b).



unbundling. Still, whether a cost-benefit analysis would become positive for ownership unbundling depends on many factors and therefore needs to take into account more than just the information management debate. Nevertheless, two arguments from the information management debate support the introduction of ownership unbundling for DSOs.

The first argument relates to the neutrality of the unbundled DSO, who is not allowed to be active in the competitive realm of the electricity sector. Therefore, the ownership unbundled DSO would have no incentive to restricting access of third parties to the information in smart grids. Competition based on information management could evolve. Second, the coordination problem could be reduced with an ownership unbundled DSO being responsible for information management. If the DSO manages both, the network and information this is likely to lower transaction costs. Similar arguments were raised by Ruester et al. (2013).<sup>14</sup>

However, the introduction of ownership unbundling might result in inefficient incentives for the DSO. The DSO might have the incentive to hamper the development of information management. Similar concerns were raised by Brunekreeft & Ehlers (2006) with respect to the incentives of ownership unbundled DSOs to support the development of DG. We will show that their argument gains relevance if it is applied to information management in smart grids. The argumentation of Brunekreeft & Ehlers (2006) is based on the potential of DG substitute network investments. However, given an incentive regulation scheme network investments are the main driver for the DSOs revenues. The diffusion of DG would lower the DSOs revenues, because the need for network investments would be reduced by DG.

Similar effects can be expected from information management. Information management provides a platform for new services. Some of these services could in effect substitute network investments by the DSO. Examples for such services are peak-shaving mechanisms or energy-efficiency services. Peak-shaving would have a direct effect on network investments, as lower peaks in demand reduce the need for network reinforcement. Services that increase energy efficiency would reduce the income from network charges as these are related to the electricity consumed, at least in the case of private households. Both services would reduce the DSOs income. These are only two examples for services that could reduce the revenue of an

---

<sup>14</sup> van Werven & Scheepers (2005) point in the same direction when they stress that an efficient development of DG and related services can only evolve under an ownership unbundling regime on the distribution grid level.

unbundled DSO under an incentive regulation scheme. A profit-maximizing DSO being responsible for information management therefore might have an incentive not to support the development of services based on the information management. Therefore, it can be concluded that the arguments raised against ownership unbundling by Brunekreeft & Ehlers (2006) gain relevance with the introduction of information management. Following this argumentation the introduction of ownership unbundling might hamper the development of information management and thereby reduce efficiency.

Importantly though, the argumentation above is not applicable to every regulation scheme but only refers to the case of the incentive regulation scheme based on a cost-based approach.<sup>15</sup> Other regulation schemes might better align the incentives of an unbundled DSO with the support of information management.

This short evaluation is not exhaustive and therefore should not be considered as a final evaluation of the effect between information management and ownership unbundling. Still, given a cost-based incentive regulation scheme it seems not economically efficient to introduce ownership unbundling for information management in smart grids.

## **6 Conclusion**

The development towards smart grids requires not only a technological but an institutional change as well. With an increasing number of active parties in smart grids, from small DG operators to services providers for energy efficiency measures, the need for the exchange of information is increasing. So far, information processing was an integrated task of the DSO as they were the only parties interested in the information. This is changing.

Information in smart grid serves at least two purposes: First, information is needed to balance the increasingly distributed generation and consumption. Second, information can be used by commercial parties to develop new services and products for costumers, i.e. households and commercial/industrial businesses. Therefore, the collection, storage and exchange of

---

<sup>15</sup> For details about the different incentive schemes see (Joskow, 2008). Similar regulatory systems are currently applied in Czech Republic and France (Perrin, 2013).

information is becoming a new task in the electricity supply chain. We defined this task as information management.

In this paper it was discussed how the institutional environment of smart grids looks like in Europe and how different governance models for information management could fit into this environment. Based on the existing roles in the energy system (generation, network operation, retail, third parties) we differentiated two general governance approaches (integrated vs. separated from the operation of the monopolistic distribution networks) and evaluated both concepts with respect to coordination between the network operator and other parts of the supply chain as well as their effects on competition.

Our analysis revealed that delegating information management to either of the existing roles in the energy system results in a tradeoff between coordination and competition on the distribution grid level. Neither the integrated solution (information management as an integrated task of the DSO) nor the separated concepts result in an efficient balance between coordination and competition. For the integrated solution the regulatory effort to secure competition will be high, while the separated solutions will require significant efforts to develop a market based coordination mechanism to align network operation with the commercial activities within the electricity sector.

Based on these findings we conclude that to achieve an efficient balance between coordination and competition additional governance structures for information management are required (for example see Buchmann et al. (2015)). Further research is necessary to define how these new governance approaches might be implemented to establish a level playing field in smart grids based on a neutral and non-discriminatory information management.

## References

- Brunekreeft, G., Buchmann, M. and Meyer, R., *New developments in electricity markets following large-scale integration of renewable energy*, forthcoming in Finger, M., Jaag, C. (Edit.): *The Routledge Companion to Network Industries*. Routledge (December 11, 2015).
- Brunekreeft, G. 2015, “Network unbundling and flawed coordination: Experience from the electricity sector”, *Utilities Policy* (34), 11-18.
- Brunekreeft, G. Ehlers, E. 2006 , “Does ownership unbundling of the distribution networks distort the development of distributed generation?”, *Competition and Regulation in Network Industries* 1(1).
- Brunekreeft, G. Friedrichsen, N. 2010, “Vertical unbundling, the coordination of investment, and network pricing”, *Bremer Energy Working Papers* 3.
- Brunekreeft, G. Keller, K. 2001 , “Sektorspezifische Ex-ante-Regulierung der deutschen Stromwirtschaft”, *Diskussionsbeiträge//Institut für Verkehrswissenschaft und Regionalpolitik* .
- Brunekreeft, G. Meyer, R. 2009 , *Fallstudien zur Netzökonomie*, Knieps, G. and Weiß, H.-J, chapter Entflechtung auf den europäischen Strommärkten: Stand der Debatte.
- Buchmann, M., Brandstät, C., Brunekreeft, G. and Friedrichsen, N. 2015, “*Information governance in smart grids – a common information platform (CIP)*”, Bremen Energy Working Papers No. 18, Jacobs University, Bremen.
- CEER 2012, *Benchmarking report on meter data management*, Council of European Energy Regulators. Brussels.
- CEER 2013a, *Status review of regulatory aspects of smart metering*, Council of European Energy Regulators. Brussels.
- CEER 2013b, *Status review on the transposition of unbundling requirements for DSOs and closed distribution system operators*, Council of European Energy Regulators. Brussels.
- CEN-CENELEC-ETSI 2012, *Smart grid reference architecture*, Smart Grid Coordination Group.
- Cossent, R., Gomez, T. Frias, P. 2009, “Towards a future with large penetration of distributed generation: Is the current regulation of electricity distribution ready? regulatory recommendations under a european perspective”, *Energy Policy* 37(3), 1145–1155.

- de Joode, J., Jansen, J. C., van der Welle, A. J., Scheepers, M. J. J. 2009, “Increasing penetration of renewable and distributed electricity generation and the need for different network regulation”, *Energy Policy* **37**(8), 2907–2915.
- de Nooij, M., Baarsma, B. 2009, “Divorce comes at a price: An ex ante welfare analysis of ownership unbundling of the distribution and commercial companies in the dutch energy sector”, *Energy Policy* **37**(12), 5449–5458.
- DECC 2013, *The smart metering system*, Department of Energy and Climate Change. London.
- dena 2013, *distribution grid study 2013*, Deutsche Energie Agentur.
- E-Bridge, IAEW, OFFIS 2014, *Moderne Verteilernetze für Deutschland (Verteilernetzstudie)*, Study for the Federal Ministry of Economics and Technology (BMWi).
- 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.
- ETPSG 2010, *Strategic deployment document - final version*, European Technology Platform for Electricity Networks of the Future. Brussels.
- EUCOM 2003, *Directive 2003/54/EC of the European parliament and of the council of june 26, 2003, concerning common rules for the internal market in electricity and repealing directive 96/92/ec*, European Commission. Brussels.
- EUCOM 2007, *DG competition report on energy sector inquiry*, European Commission. Brussels.
- EUCOM 2009, *Directive 2009/72/EC of the European parliament and of the council of 13 july 2009 concerning common rules for the internal market in electricity and repealing directive 2003/54/EC*, European Commission. Brussels.
- EUCOM 2011, *Energy markets in the european union 2011*, European Commission. Brussels.
- EUCOM 2014, *Report on the ITO Model*, European Commission, SWD(2014) 312.
- Groebel, A. 2013, “Unbundling models in the eu and certification of tsos in germany”, *10th EU-US Energy Regulators Roundtable – Session V*.
- Haney, A., Jamasb, T., Pollitt, M. 2009, “Smart metering and electricity demand: Technology, economics and international experience”, *Cambridge Working Papers in Economics* **905**.
- Henry, C. 1974, “Investment decisions under uncertainty: The "irreversibility effect"”, *American Economic Review* **64 No. 6**, 1006–1012.

- Hoeffler, F. Kranz, S. 2011, “Legal unbundling can be a golden mean between vertical integration and ownership separation”, *International Journal of Industrial Organization* **29**(5), 576–588.
- Jagstaidt, U. C. C. 2014, *Smart Metering Information Management - Gestaltungsansätze für das Informationsmanagement und für Geschäftsmodelle der Marktakteure in der Energiewirtschaft*, Vol. 73, Cuvillier Verlag.
- Jagstaidt, U. C. C., Kossahl, J. Kolbe, L. M. 2011, “Smart metering information management”, *Wirtschaftsinformatik* **53**(5), 313–317.
- Joskow, P. L. 1996, “Introducing competition into regulated network industries: from hierarchies to markets in electricity”, *Industrial and Corporate Change* **5**(2), 341–382.
- Joskow, P. L. 2008, “Incentive regulation and its application to electricity networks”, *Review of Network Economics* **7**(4), 547–560.
- Joskow, P. L. Schmalensee, R. 1983, “Markets for power: an analysis of electrical utility deregulation”, *MIT Press Books* **1**.
- Knieps, G. 2006, *Sector-Specific Market Power Regulation versus General Competition Law: Criteria for Judging Competitive versus Regulated Markets*, Electricity Market Reform: An International Perspective, Sioshansi, F. P. and Pfaffenberger, W., Oxford, UK, pp. 49–74.
- Knieps, G. 2011, “Regulatory unbundling in telecommunications”, *Competition and Regulation in Network Industries* **12**, **4**, 344–361.
- Knieps, G. Zenhäuser, P. 2010, “Phasing out sector-specific regulation in european telecommunications”, *Journal of Competition Law & Economics* **6** (4), 995–1006.
- Kuenneke, R. Fens, T. 2007, “Ownership unbundling in electricity distribution: The case of the netherlands”, *Energy Policy* **35**(3), 1920–1930.
- Markovic, D. S., Zivkovic, D., Branovic, I., Popovic, R. Cvetkovic, D. 2013, “Smart power grid and cloud computing”, *Renewable and Sustainable Energy Reviews* **24**, 566–577.
- Meyer, R. 2012, “Vertical economies and the costs of separating electricity supply-a review of theoretical and empirical literature”, *Energy Journal* **33**(4), 161–185.
- Mulder, M., Shestalova, V. Lijesen, M. 2005, *Vertical separation of the energy-distribution industry: An assessment of several options for unbundling*, Technical Report 84, CBP, The Hague.
- Newbery, D. M. 1997, “Privatisation and liberalisation of network utilities”, *European Economic Review* **41**(3), 357–383.

- Nielsen, E. 2010, “Network investments and the integration of distributed generation: Regulatory recommendations for the dutch electricity industry”, *Energy Policy* **38**(8), 4355–4362.
- Nillesen, P. H. L. Pollitt, M. G. 2011, “Ownership unbundling in electricity distribution: Empirical evidence from new zealand”, *Review of Industrial Organization* **38**(1), 61–93.
- Pal, R. Hui, P. 2013, “Economic models for cloud service markets: Pricing and Capacity planning”, *Theoretical Computer Science* **496**, 113–124.
- Perrin, L. 2013, *Mapping power and utilities regulation in Europe*, EYGM Limited.
- Pollitt, M. 2008, “Electricity reform in argentina: Lessons for developing countries”, *Energy Economics* **30**(4), 1536–1567.
- PWC 2013, *Splitsing in de energiesector - een verdeeld of onverdeeld succes?*, PriceWaterhouseCoopers, Amsterdam.
- Ropenus, S., Jacobsen, H. K. Schröder, S. T. 2011, “Network regulation and support schemes—how policy interactions affect the integration of distributed generation”, *Renewable Energy* **36**(7), 1949–1956.
- Ruester, S., Pérez-Arriaga, I., Schwenen, S., Batlle, C. Glachant, J.-M. 2013, *From distribution networks to smart distribution systems: Rethinking the regulation of european electricity DSOs*, final report,, Technical report, Topic 12 FP7 THINK project.
- SEO 2006, *De welvaartseffecten van het splitsingsvoorstel – een overkoepelend beeld*, SEO Amsterdam.
- SGTF 2013, *EG3 first year report: Options on handling smart grids data*, EU Commission Task Force for Smart Grids - Expert Group 3. Brussels.
- van Werven, M. Scheepers, M. 2005, *Dispower - the changing role of energy suppliers and distribution system operators in the deployment of distributed generation in liberalised electricity markets*, Technical Report C–05-048, ECN.
- Voß, S. and Gutenschwager, K. 2001, *Informationsmanagement*, Springer.
- Wissner, M. Growitsch, C. 2010 , “Flächendeckende einföhrung von smart metern – internationale Erfahrungen und Rückschlüsse für Deutschland”, *Zeitschrift für Energiewirtschaft* **34**(2), 139–148.