Utilities Policy xxx (2017) 1–10

Contents lists available at ScienceDirect

Utilities Policy

journal homepage: www.elsevier.com/locate/jup

Governance of data and information management in smart distribution grids: Increase efficiency by balancing coordination and competition

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ARTICLE INFO

Article history:
Received 13 October 2015
Received in revised form
13 January 2017
Accepted 13 January 2017
Available online xxx

Keywords:
Smart grid
Data management
Information management
Governance
Coordination

ABSTRACT

Smart grids should increase efficiency by enhancing coordination at the electricity distribution grid level and facilitating new market competition for services on a level playing field. Information management has become a new task in the electricity supply chain and an essential component of smart grids. Governance of information management should balance the goals of coordination and competition. Based on the analysis in this paper, existing participants in the electricity supply chain and the corresponding governance approaches appear to be unsuited to this goal and new governance approaches and roles are needed.

1. Introduction

To reduce the costs of integrating renewable generation into electricity distribution grids, the exchange of data about demand, supply, and potential flexibilities must 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.[1] Among others, key drivers for these costs are the distribution networks. Significant investments are required for these networks to promote the integration of renewable energy resources within the next decades. However, network expansion is costly. Alternative approaches to integrating renewable energy resources into the distribution grid are based on information and communication technologies (ICT), organized under the concept of smart grids. Though there are various definitions for smart grids, the definition of the European Technology Platform for Electricity Networks of the Future (ETP SmartGrids) of the European Commission underlies the current scientific discussion:

> ”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.[2] dena (2013) calculated for Germany that smart applications based on ICT could reduce network investments on the distribution grid level till 2032 by 45%.[3] Similar results were developed by E-Bridge et al. (2014). They calculated that the total costs for distribution

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[1] Germany was one of the first countries to define binding goals for CO_2-reduction and high shares of renewable electricity supply (RES) till 2050. Furthermore, Germany plans to phase out all nuclear power plans till 2022. Both policies together are summed up under the headline of the energy transition. Due to the energy transition several changes in the institutional framework of the electricity sector are currently discussed, among them the governance of data and information management. Therefore, we focus our analysis on Germany and the European situation.

[2] in Germany distribution grids are defined as the networks up to 110kV, transmission networks operate at 230 kV or 400 kV.

[3] 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.

http://dx.doi.org/10.1016/j.jup.2017.01.003

network expansion in Germany could be reduced by 60%.

These studies illustrate that the implementation of ICT in the distribution grids can help promote 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. Accordingly, investments in the network should be avoided as long as there is a cheaper alternative, e.g., load shifting. Second, smart grids should facilitate new business opportunities for market parties. In other words, it is also expected that smart grids will increase competition in the electricity sector. Both, coordination and competition should increase efficiency 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 data exchange (e.g., distributed generation owners, storage providers, and consumer participating in demand side management programs). These parties might be incumbents from the energy sector, but new market entrants as well.[4] The data exchange between the participants in smart grids (i.e., data handling) is a new and increasingly important step in the electricity supply chain. From an institutional perspective, the primary task of data handling is to ensure that all eligible parties have the same access to the same data; that is, data should be handled on a level playing field. The question then becomes, who should become responsible for this task?

Several issues must be addressed in this context, from sustainability issues, to privacy concerns, to IT operations. Our analysis focuses on an economic evaluation from a new institutional perspective and on the question of which party should become responsible for the operation of the information management system. The paper is structured as follows. Section 2 elaborates further on the issue of data handling and defines information management in smart grids. Section 3 specifies the institutional environment of information management in the energy sector, specifically the liberalization of the energy sector and the different participants that could become responsible for information management in smart grids. Section 4 discusses resulting governance approaches for information management based on the identified roles. Specifically, three cases are discussed:

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 system operator (DSO). For the network operators we discuss two options that either treat information management as part of the regulated business (i.e., an integrated task) or as a responsibility of the network operator, but separated from the regulated business (e.g., via organizational firewalls similar to those used in the market unbundling process).
3. Information management as a new service provided by the market actors (incumbents or third parties) from the competitive parts of the energy system (generation and retail services) could become responsible for information management.

Each of the three cases illustrates the challenge of coordination between the DSO and network users in smart grids. From a transaction-cost perspective, integration of the information management by DSOs into their regulated business seems favorable. However, this might result in incentives for DSOs to discriminate against non-associated market parties. The tradeoff between coordination and competition is identified. To address this tradeoff, Ruester et al. (2013) propose further unbundling of the DSOs. The potential shortcomings of such a governance approach for information management is discussed. The conclusion, in Section 5, is that none of the identified roles in the energy sector could govern information management and at the same time adequately balance the goals of coordination and competition.

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

Research about the governance of information management is evolving alongside the smart meter rollout in Europe. The European Union requires each member state to implement smart meters for at least 80% of all customers, if a cost-benefit analysis indicates economic potential (EUCOM, 2009). In Europe, only Sweden and Italy have finalized the rollout thus far. Sixteen other member states are planning implementation through 2020, though targets vary from 15% to 80% (CEER, 2013a).

Basically, two models for governing the smart meter rollout are discussed: a regulated approach, with the DSO being responsible for the rollout and a competitive (i.e., unbundled) approach, which leaves implementation to the market. In their summary analysis, Haney et al. (2009) conclude that institutional design can have a significant effect on the results of 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 DSO (e.g., in the Netherlands), some have established an unbundled solution with a competitive metering market (e.g., the UK and Germany, although their solutions differ significantly) (Wissner and Growitsch, 2010).

A parallel governance debate concerns the handling of data from smart meters. The EU Commissions Smart Grids Task Force 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 model is based on standardized market roles. Both the regulated and the market-based approaches are supposed to ensure neutral and non-discriminatory data management and thus help establish a level playing field in smart grids. Ruester et al. (2013) investigated in greater detail how the regulated concept with the DSO responsible for the data management fits into the current institutional framework. From their point of view a further unbundling of DSOs is required to ensure non-discriminatory data management (Ruester et al., 2013).

The discussion about data exchange in smart grids has its roots in the debate over the smart meter rollout. The term data handling was applied to summarize the ICT-related processes for transporting data from the smart meter to the recipient. However, the term data handling falls short in terms of other relevant aspects. Data in smart grids must be allocated, but it also must be stored, aggregated and verified. Governance involves not just the physical flow of data, but the management of the data exchange as well, i.e., who should be 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 and Gutenschwager (2001), information management involves the planning, purchasing, processing, distribution, and allocation of information as a resource for the preparation and support of decision-making processes. Information management implies the design of a framework to efficiently and effectively accomplish these tasks. Applying the information

[4] 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).

management concept to the data exchange challenge in smart grids follows 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) specify the required processes within the information management system to support the data exchange enabled by smart metering.[5]

Information management in smart grids is a new task in the energy system. So far the exchange of data has been limited to the bilateral data exchange between two parties, e.g. in the process of supplier switching. Several questions evolve in the context of this new task. From an institutional perspective, it is 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. Special emphasis is placed on the institutional environment in the electricity sector that defines the different participants who could become responsible for information management. This institutional environment is described briefly in the next section, followed in Section 4 by a discussion of the different governance approaches for information management based on the identified roles.

3. The institutional environment of information management in smart grids

The institutional environment of smart grids is characterized by regulation as well as the liberalization of the energy sector. Prior to the liberalization a hierarchical system existed in the electricity sector (Joskow, 1996). Integration was mainly motivated by the gains from vertical and horizontal coordination within monopolistic utilities that operated national and transnational transmission networks and local distribution networks.[6] The monopolies essentially controlled the major stages of the electricity supply chain. This market structure was generally accepted until economists began to specify the efficiency potential that could be realized by introducing competition in generation by “unbundling” the network monopolies (Joskow and Schmalensee, 1983). Though the arguments for competition were manifold, Joskow and Schmalensee (1983) stressed the complexity of required coordination mechanisms (i.e., contractual relations) to replace the internal planning processes of integrated utilities. For our purposes, these contractual relations can be characterized as information exchange across the different stages of the electricity supply chain.

The main argument against unbundling the transmission 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 among unbundled companies, as long as the market has not established efficient coordination mechanisms. With unbundling, coordination of the competitive components of the supply chain and the networks becomes especially relevant for investment decisions into the network infrastructure. Coordination requires information exchange between the generation companies and network operators (see Brunekreeft and Meyer, 2009; Brunekreeft, 2015 for details). However, an efficient market based coordination mechanism could solve this problem. In their analysis of alternative approaches, Brunekreeft and Friedrichsen (2010) found that some mechanisms, such as locational pricing, could establish efficient market-based coordination (Brunekreeft and Friedrichsen, 2010).[7]

For Europe, it has been argued that the benefits of integration in terms of coordination do not outweigh the benefits of competition (EUCOM, 2007), at least for the transmission grids. Market restructuring has focused primarily on unbundling transmission and this provides the basis for considering a comparable institutional framework at the distribution grid level.

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

The current institutional framework is based on the third legislative package of the EU, by which the Commission introduced three different options for unbundling transmission: (1) ownership unbundling, (2) creation of an Independent System Operator (ISO), and (3) creation of an Independent Transmission Operator (ITO). Full Ownership Unbundling prohibits joint ownership of network, generation, or retail assets within one firm. The ITO model allows companies to retain both network ownership and management, but puts strong limitations on cross involvement of employees to assure independence of the network. The ISO model requires an independent entity, separate from transmission asset ownership, to take over system operation of the network. With an ISO the integrated firm can retain ownership of network and generation assets.[8]

The regulations within the Third Electricity Directive were motivated by the prior experiences with weaker forms of unbundling. In particular, 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 required the network operator to be independent at least in terms of its legal form, organization, and decision-making, from activities unrelated to transmission (i.e., generation and retail services; EUCOM, 2003). This includes unbundling of accounts, operations, and information. The idea behind this model 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 creating ”firewalls” that prohibit such information flows within one integrated company (Brunekreeft and Keller, 2001). Still, a legally unbundled network operator can be part of a holding company that owns generation and retail subsidiaries as well.

Evaluating the outcomes of the unbundling process in 2007, the Commission concluded that legal unbundling did not sufficiently promote competition in the electricity sector:

[5] 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.

[6] Transmission (high voltage) networks are operated by one or a few Transmission System Operators (TSO) per country. Distribution (medium and low voltage) networks connect the end users to the electricity network and are more fragmented in many European states (Germany has more than 850 distribution network operators).

[7] However, these instruments are not applied in Europe.

[8] 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. 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, and Hungary (Groebel, 2013).

Please cite this article in press as: Buchmann, M., Governance of data and information management in smart distribution grids: Increase efficiency by balancing coordination and competition, Utilities Policy (2017), http://dx.doi.org/10.1016/j.jup.2017.01.003

"[…]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 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 at the transmission level, this was not mandated 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 (EUCOM, 2014). Further unbundling of the transmission networks beyond the ITO model is therefore not an issue for now.

The institutional framework of the distribution grid is different from that of the transmission grid. Distribution networks are currently subject to legal unbundling (EUCOM, 2009). However, legal unbundling is only applied to those DSOs that have more than 100,000 customers. DSOs with fewer customers do not have to unbundle and can remain an integrated part of the 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 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). The legally unbundled DSOs that are not subject to the de-minimis rule own large parts of the overall network in most member states of the EU. Typically, despite their small number, these larger DSOs own roughly 95% of the national markets; exceptions are Denmark (43% market share of small DSOs) or Austria (12% market share 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 at the distribution grid level (e.g., 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., Belgium, Bulgaria, and the UK; CEER, 2013b).

Fig. 1 summarizes the institutional framework for information management in the electricity sector.

On a general level the institutional environment in the electricity sector defines four participant roles that could become responsible for information management: (1) regulated entities from the network monopolies, (2) established incumbents from the generation or retail segment, (3) third parties that are already active in the electricity sector, or (4) third parties that enter the electricity sector specifically to become responsible for information management. The next section considers the different governance approaches that assign the responsibility for information management to these alternative roles.

4. Governance models for information management

Information management could become a task of any of the four roles defined above. Three basic approaches to govern information management can be differentiated:

1. One institution from the four roles could be responsible for governing the information management system for a specific region (e.g., a country in whole or in part). This would result in a monopoly for information management.
2. The distribution network operators could be responsible for operating the information management systems for their networks.
3. The competitive parts of the energy system (generation or retail services) could be responsible for information management.

With regard to the first approach, based on economic theory, information management itself does not qualify as a monopoly or a monopolistic bottleneck as it is known. Knieps (2006) identified two criteria that 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; in other words, the network cannot be readily repurposed once built.[9] The existence and extent of irreversible costs determine whether or not new players are willing to enter a market. In contrast, the incumbent player has already incurred these irreversible costs, and this affects its strategic behavior. An example for such strategic behavior would be that the incumbent increases prices to a level where all consumers would be willing to switch to another supplier, but there is no such competitor due to the irreversible costs. For incumbents, irreversible costs tend to secure market power and thereby allow for inefficiencies, as these inefficiencies do not directly invite competition (Knieps and Zenhäuser, 2010).

Taking a closer look at information management reveals economies of scale, such as those associated with storage capacities for the data exchanged in smart grids. Still, there are potential substitutes for information management. In the following, we briefly discuss the economies of scale associated with cloud computing, which serves as a first approximation for the case of information management. Cloud computing describes a network of different servers and the data stored or services operated on these servers can be accessed via an internet connection (Markovic et al., 2013).

Considerable economies of scale in cloud computing are anticipated (Pal and Hui, 2013). Competition among different IT companies in this area (e.g., Google, Amazon, Microsoft, etc.) is also growing. The services provided by both cloud computing and information management require large data storage facilities that can be accessed externally from eligible service providers and their customers. Furthermore, both cloud computing and information management, require huge data transfers from customers to storage providers. Therefore, it seems likely that developments within the cloud-computing market might serve as a first approximation for potential developments in the information management realm of smart grids. As in cloud computing, however, potential substitutes for the provision of information management in smart grids are likely to evolve. Therefore, smart-grid information management does not seem to qualify as a monopolistic bottleneck or justify a monopolistic governance approach.

Independent from the economic evaluation above, information management could be considered an institutional monopoly. This requires a governmental decision to have only one information management operator in a specific region (a county in whole or in

[9] Irreversibility was analyzed in greater detail with respect to decisions, see Henry (1974).

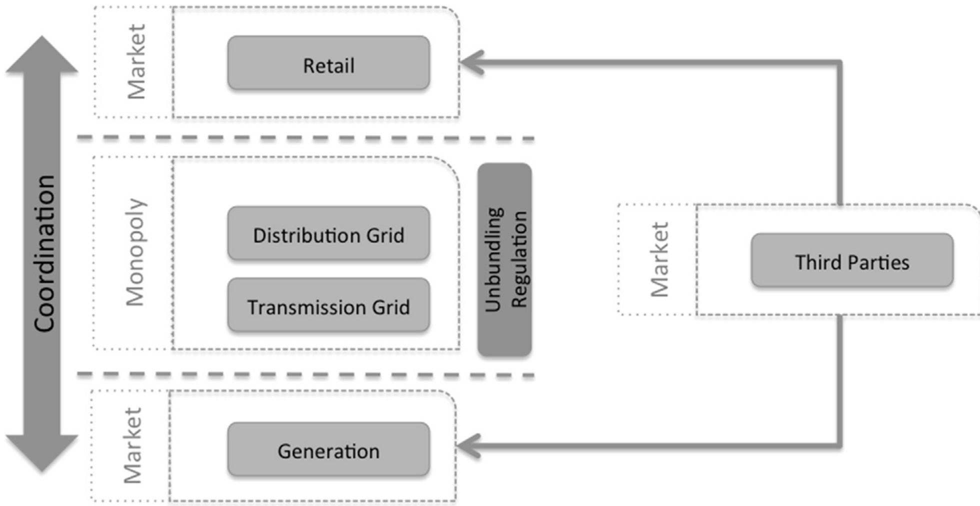


Fig. 1. The different roles defined by the institutional framework for information management in the electricity sector.

part), in effect foreclosing potential substitutes. Institutional monopolies are thus 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).[10] Information management can thus becomes a local monopolistic bottleneck by law. There are several arguments that support the application of institutional monopolies to the case of information management, e.g. security and privacy issues.

The second group of governance models delegates the information management task to the network operators that already operate monopolistic infrastructures. Here, two approaches can be differentiated. Information management could be provided as an integrated task by the operator of the electric distribution (or transmission) networks; that is, information management would become part of the regulated business of the network operator and 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 accomplished 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 of '(legal) unbundling of information management' to ensure that the network operators do not misuse their market power on the network side to influence the information management business.

Given effective separation of information management from the regulated tasks of the network operators, 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 operates and third parties in the market for information management). However, several issues would need further specification to define a system with both network and information management operators.[11]

In the third approach, 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 this evaluation, two basic models of information management as a new task in the electricity supply chain emerge. On the one hand, information management could be provided by an operational or an institutional monopoly. On the other hand, information management could be separated from network operation, independent of the monopolistic infrastructure, and competitive. In the competitive model, any party other 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) that are not yet active in this area. Alternatively, information management could be a task of the network operators, but separated by firewalls from network operations. Theoretically, the network operator could become a competitive provider of information management.

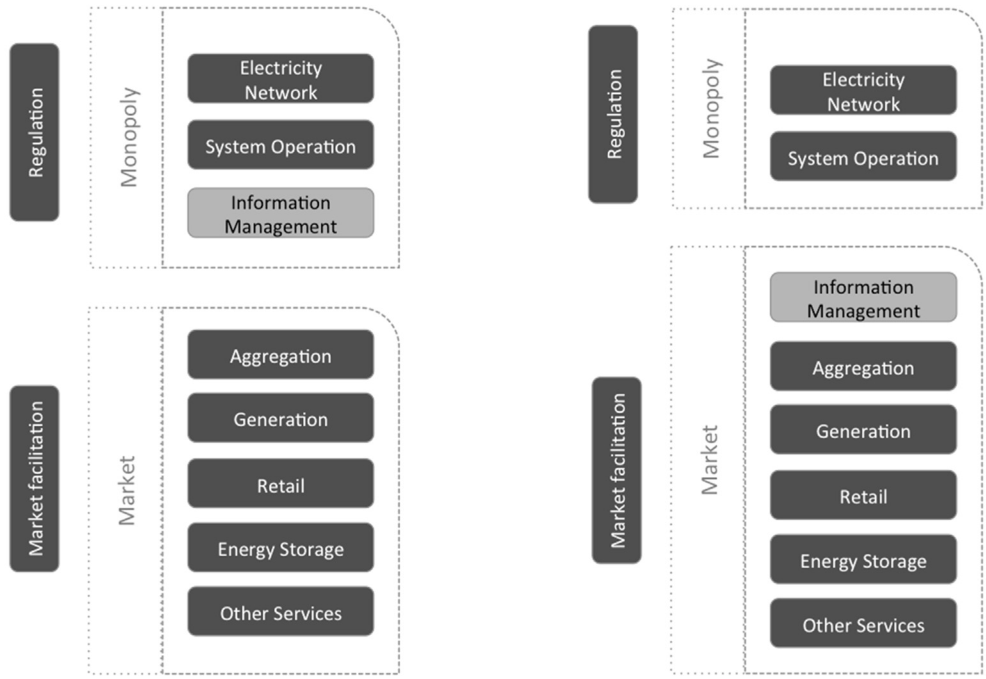
Given a solution that separates information management from the networks, access to the electricity infrastructure would be regulated based on established regulatory schemes. Additionally, information management itself would be part of the competitive environment and therefore subject to competition law and other applicable regulations (unrelated to monopoly). Fig. 2 illustrates the integrated and separated approaches.

These alternative governance models for information management can be evaluated according to two specific institutional criteria, which indicate the potential of the governance approach to increase efficiency in the electricity sector:

1. Coordination: Do the different governance approaches for information management have an effect on the coordination on the distribution grid level?
2. Competition: Does the governance model facilitate competition to increase efficiency by providing appropriate incentives for the party that governs information management?

[10] 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.

[11] Such an approach requires quite some effort to ensure 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 then 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.



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

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

Fig. 2. Information management as a separated or integrated task from/within the regulated operation of the electricity networks.

4.1. Coordination in distribution grids

In the given context, coordination describes the exchange of information within the electricity supply chain. Before liberalization, coordination was a hierarchical process that took place within an integrated utility company providing generation as well as network and retail services. After liberalization, the formerly integrated departments of the utilities were separated into different companies. Now the network company must coordinate externally with retailers and generation companies (Brunekreeft and Ehlers, 2006). Market-based coordination mechanisms can be introduced, potentially with similar transaction costs. In reality, the coordination between the network and the rest of the supply chain is weak and based on an imperfect system of network charges (Brunekreeft, 2015).

Consider the case of an unbundled distribution system operator and a generation company that wants to invest in distributed generation (DG). The DSO could implement location differentiated network charges to give incentives to the investor to install the DG where it would not require additional network investments. However, this can only result in efficient outcomes if the network charges reflect all costs related to the installation of DG. Brunekreeft and Ehlers (2006) argue that shallow network charges, the most common model in Europe, do not reflect all 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 other respects as well. The investor in DG does not need to consider the DSO's needs or plans for network expansion. Coordination is not possible if DG investors and network operators do not exchange information. More recently, Niesten (2010) stressed that the coordination problem in the Netherlands has already slowed the development of DG, which supports the argument raised by Brunekreeft and Ehlers (2006). With an increasing share of RES the coordination problem gains relevance (Ropenus et al., 2011; and Cossent et al., 2009).

The federal government of Germany has considered a mechanism to reduce the cost of the missing coordination between DG and the network. The idea is to allow the network operators to curtail 3% of annual electricity production by the connected DG. Calculations by E-Bridge et al. (2014) reveal a potential to reduce network expansion costs by 30% when the curtailment approach is applied. The Federal Government introduced a rule to allow the curtailment by the DSO in 2016. The necessity of the curtailment rule delivers proof for the existence of the coordination problem in Germany.

Presumably, coordination will become even more complex with the introduction of smart grids in two regards. First, the number of stakeholders in the electricity system increases. Their actions must to be coordinated to balance demand and supply. New stakeholders can evolve on the production side, as more DG is owned by small investors (including households) or on the consumption side, where more consumers actively participate in the electricity system through demand response mechanisms.

Second, information in smart grids must be exchanged at higher volumes as well as with higher resolution. While grid operation might not require data for every second of every connection to the grid, service providers on the market might have an interest in this detailed data and customers might demand these services. New services are likely to have direct effects on the operation of the distribution grid. For example, demand response aims to shape consumption 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 at the distribution grid level. The effect of these new services might be marginal today, as most programs 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 can help to solve this problem efficiently, for example by reducing transaction costs.

Can information management reduce the transaction costs between the network and the other parts of the supply chain? In other words, can information management have a positive effect on the coordination problem at the distribution grid level? To address this question, two assumptions are made.

First, it is expected 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 – will itself reduce transaction costs for the DSO. The collection and aggregation of data in particular 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 these data through the information management provider. This might even be true if several different information management providers are active in a DSO's grid area. However, with an increasing number of different information management providers in a network area, the coordination gains from the introduction of information management might be reduced, as the DSO then again needs to exchange information among several different parties. Nonetheless, 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 lowest if the distribution network operator integrates information management into its regulated business. In this case, information management is provided by an integrated department of the network operator and can directly access the required data via internal processes. However, this is only true when information management is integrated into the hierarchy of the network operator and becomes part of the regulated business as well.

The situation changes if information management is a task of a separated department of the DSO that is 'unbundled' from the network business via firewalls. If 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 when an external company provides the information management to the network operator. In both cases, the network operator must contract with the information management company to access the relevant data.

To conclude, coordination becomes more important in smart distribution grids and an integrated approach that delegates the new task information management to the regulated network operators is expected to reduce coordination costs, at least from a theoretical perspective.

4.2. Competition in distribution grids

Integrating information management into the regulated business of the network operator might reduce coordination costs, but it could also undermine competition by weakening incentives for efficient behavior. Though information management would become a new task for the DSOs, the arguments against this solution are similar to those raised prior to liberalization. Joskow (1996) pointed to 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 to the system by third parties in order to increase its own profits. In addition, a grid owner who takes part in the competitive sectors could be able to cross-subsidize its activities in the market through the regulated network tariffs in the natural monopoly part of its business.[12] Newbery (1997) raised similar concerns with respect to integrated utilities that have the ability to control information and thereby discriminate against other parties.

These concerns gain importance with the introduction of smart distribution grids. Many benefits of smart grids are related to the innovation potential that comes from third parties (Erlinghagen and Markard, 2012). An integrated utility might therefore have the incentive to restrict access of third parties to the information in smart grids in order to protect its market share. If an integrated utility is responsible for information management, competition might be hampered. In an unbundled structure, these incentives to discriminate should be eliminated. Whether legal unbundling is sufficient for this purpose is still under discussion. Hoeffler and Kranz (2011) argued that legal unbundling might be the golden mean between integration and full ownership unbundling. However, Ruester et al. (2013) are skeptical about whether legal unbundling is effective. As far as the transmission system is concerned the European Commission seems to be satisfied with the effects of strong legal unbundling (EUCOM, 2014).

In comparison, a fully unbundled DSO (with no organizational relation to market parties) 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 and Baarsma, 2009; Hoeffler and Kranz, 2011; Brunekreeft, 2015), it could solve incentives to discriminate and thereby might over a solution for information management in smart grids. This solution is 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 of reducing incentives to discriminate against 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.[13]

From the above, two important implications for the governance of information management in smart grids can be extracted. First, the coordination problem at 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 information management. Still, the effect of information management on the coordination problem is stronger if it is an integrated task of the DSO. Second, given the current

[12] We would expect the regulator to secure that cross-subsidies are not possible. However, without very detailed information, this is a quite challenging task fort he regulator. This is one oft he reasons why legal unbundling was introduced: It is difficult to access all the relevant data to identify cross-subsidies.

[13] This includes that the operator of the information management is not an affiliated company of either the same holding as a legally unbundled DSO.

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institutional environment, with legal unbundling, the integrated approaches that assign information management to the DSOs might result in incentives to discriminate against third parties. In these cases, regulatory oversight would be required to promote competition on a level playing field. Therefore, a tradeoff between coordination and competition is apparent: both cannot be secured at the same time with regard to information management given the current institutional environment.

There is some uncertainty about 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.[14] In the EU's current regulatory scheme, ownership unbundling is not mandatory. So far, mandatory ownership unbundling at the distribution grid level has only been applied in New Zealand, where it was introduced in 1998, and in the Netherlands, where most DSOs have been unbundled since 2011.[15] An evaluation by Nillesen and 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 is unclear whether ownership unbundling was the reason for this temporary increase in retail competition. Other factors may have influenced the retail market at that time as well. Nillesen and Pollitt (2011) conclude that ownership unbundling might the primary solution to introducing competition in the electricity sector.

For the case of the Netherlands, different cost-benefit analyses come to different results. An evaluation by SEO (2006) found a welfare loss from ownership unbundling. This finding was also supported by de Nooij and Baarsma (2009). Based on these investigations, the costs of ownership unbundling might exceed the benefits derived from it. Ownership unbundling at the distribution grid level might even result in decreasing competition given that generation and retail services are still integrated, which could hinder independent retailers to enter the market (de Nooij and Baarsma, 2009). More recently, PWC (2013) evaluated the status of ownership unbundling in the Netherlands, concluding that expectations were not met. On the contrary, the evaluations by Mulder et al. (2005) and Kuenneke and Fens (2007) revealed a potentially positive effect of ownership unbundling at the distribution grid level under certain circumstances.

This research tends to support the 2007 decision of the European Commission not to introduce ownership unbundling at the distribution grid level. It appears that legal unbundling is sufficient to ensure neutrality and non-discriminatory access of third parties to the infrastructure.

Ruester et al. (2013) addressed ownership unbundling of the distribution grid operators with regard to 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 unbundling of the distribution networks. Whether a cost-benefit analysis would support ownership unbundling depends on many factors beyond just information management. Nevertheless, two arguments from the information management perspective support the introduction of ownership unbundling for DSOs.

The first argument relates to the neutrality of the ownership unbundled DSO, which is not allowed to be active in the competitive realm of the electricity sector. Therefore, the ownership unbundled DSO would have no incentive to restrict access of third parties to smart-grid information. Competition based on information management capabilities 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, transaction costs would be lower. Similar arguments were raised by Ruester et al. (2013).[16]

However, ownership unbundling might still introduce incentives for the DSO that reduce competition and result in less efficiency. Specifically, the DSO might hamper the development of information management. Brunekreeft and Ehlers (2006) raised this issue with respect to the incentives of ownership unbundled DSOs to support the development of DG. The diffusion of DG would lower DSOs revenues because the need for network investments could be reduced. Therefore, the DSOs support of the diffusion of DG could result in a cannibalism-effect of its own revenues. Similar effects can be expected from information management. Information management provides a platform for new services. Some of these services could in effect substitute for network investments by the DSO. Examples include 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 of services that could reduce the revenue of an unbundled DSO under an incentive regulation scheme. A profit-maximizing DSO responsible for information management therefore might have an incentive to not support the development of services based on the information management. Therefore, the argument against ownership unbundling raised by Brunekreeft and Ehlers (2006) gains relevance with the introduction of information management. Following their analysis, the introduction of ownership unbundling might hamper the development of information management and thereby forego efficiency improvement.

Importantly, however, this argument applies only to an incentive regulation scheme that relies on a cost-based approach.[17] Other regulatory schemes might better align the incentives of an unbundled DSO with the goals associated with expanding both DG and information management.

This review is not exhaustive and therefore should not be considered as a final evaluation of the relationship of information management to ownership unbundling. Still, given a cost-based incentive regulation scheme, it does not appear that introducing ownership unbundling for information management in smart grids would be consistent with the goals of economic efficiency.

5. Conclusion

The development of smart grids requires not only technological but institutional change. With an increasing number of

[14] Though the focus here is on the relation between information management and ownership unbundling, the discussion is much broader and more complex.

[15] Though not required by law, some DSOs in Belgium, Bulgaria, Romania, Portugal, Italy, and the UK are ownership unbundled (CEER, 2013b).

[16] van Werven and Scheepers (2005) similarly stress that efficient development of DG and related services can only evolve under an ownership unbundling regime at the distribution grid level.

[17] For details about the different incentive schemes see (Joskow, 2008). Similar cost-based regulatory systems are currently applied in Czech Republic and France (Perrin, 2013).

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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. Information processing has bee considered an integrated task of the DSO, as they were the only parties interested in the information, but this situation is changing.

Information in smart grid serves at least two purposes. First, information is needed to balance increasingly distributed generation and consumption. Second, information can be used by commercial parties to develop new services and products for electricity customers (households and commercial or industrial businesses). Therefore, information management – the collection, storage and exchange of information – is a new and important task in the electricity supply chain.

This paper considered the institutional environment of smart grids 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 services, and third parties) two general governance approaches were differentiated (integrated with the monopolistic distribution networks vs. separated from the operation of the monopolistic distribution networks). These were evaluated with respect to their effect on coordination between the network operator and other parts of the supply chain as well as their effect on competition.

The analysis revealed that delegating information management to one of the existing roles in the energy system results in a tradeoff between coordination and competition at the distribution grid level. Neither the integrated solution (information management as an integrated task of the DSO) nor the separated solution resulted in an ideal balance between coordination and competition. For the integrated solution, the regulatory effort to promote competition will be high, while the separated solution requires significant effort in terms of developing a market-based coordination mechanism to align network operation with the expanding commercial activities within the electricity sector.

These findings suggest that to achieve an efficient balance between coordination and competition, additional governance structures for information management are needed (see Brandstätt et al., 2017). 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 neutral and non-discriminatory information management.

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