

Buchmann, Marius

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Marius Buchmann

Information Management in Smart Grids –  
the need for decentralized governance  
approaches

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**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)

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# **Information Management in Smart Grids - the need for decentralized governance approaches**

Marius Buchmann - Jacobs University Bremen - Bremer Energy Research

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## **Abstract**

Information management secures the efficient exchange of data (e.g. from smart metering) in smart grids. Currently, national as well as regional information management systems are being developed. We discuss how the size of an information management system, i.e. the region covered by and the number of users connected to it, has an influence on the level of innovation in the process of the data exchange. Based on insights from the theory of fiscal federalism we argue that neither of the extremes of national (central) and decentralized governance approaches for information management will be optimal. We discuss how the market can determine the optimal degree of decentralization. If information management shall enable smart grids, then we show that the network operator needs to be able to incentivize network users to join and participate in an information management system to internalize externalities. Then, the size of the governance of information management systems will be linked to the network areas on the distribution grid level.

*Keywords: Smart Grid, Information Management, data exchange, fiscal federalism, size*

## **1 Introduction**

The roll-out of electricity smart meters triggered a discussion about different data handling and information management models in Europe (cf. Ruester et al. (2013) & van den Osterkamp (2014)). However, this discussion about the governance of information management in smart grids falls short to define how the size of an information management system should be determined. Rather, the different concepts under discussion try to define which entity should become responsible for information management. Thereby, the size of an information management system is defined implicitly by the original function an entity already fulfils within the energy system (e.g. by the service areas of the network operators, suppliers etc.). We take a different perspective in this paper. Within our analysis we strive to identify criteria

that help to define the (optimal) size of an information management system, independent from the fact who actually operates the system.

Information management here refers to the collection, aggregation and distribution of data (e.g. from smart metering). Thereby, information management serves as an enabler for smart grids and innovative services, which are anticipated to evolve. The term smart grids describes the integration of information and communication technology (ICT) into the electricity distribution networks (for a detailed definition see ETPSG (2010)). The primary driver for smart grids is the cost efficient integration of renewable electricity supply (RES). The availability and exchange of data (e.g. on electricity consumption and production) is a key requirement for smart grids. Information management facilitates the data exchange between the different parties in the energy sector. This is why information management has an important role as an enabler of smart grids.

So far, the discussion about the exchange of data from smart metering focused on neutral access to information and how to avoid incentives to discriminate third parties. Besides these two aspects the facilitation of innovation becomes an important criterion for the governance of information management as well. A key driver behind smart grids is the potential of smart technologies to reduce the costs of the integration of renewable energies into the electricity system, e.g. via substituting grid investments (dena 2012). Furthermore, local balancing of load and demand should become more flexible. Data exchange is the key requirement to unlock these flexibility options. From today's perspective, it is difficult to anticipate how these innovative services could look like. However, the governance of information management should ensure that innovation is possible (CEER 2014)..Within this paper the focus is on the latter: Innovation here refers to developments in the governance approach (a future-proof governance approach), not to the creation of innovative products based on the governed system. Based on these three criteria the

task of the governance approach of information management can be summarized as follows: develop a level playing field that secures innovation as well as neutral and non-discriminatory access to information for all eligible parties.

Out of the three criteria (non-discrimination, neutrality and innovation) the first two are primarily determined by the institutional design, but rather independent from the size of the governance approach. This is different in the case of innovation. Here, the question has already been raised whether the size of a governance approach has an influence on the level of innovation within the governed system. This question is specifically addressed by the theory of fiscal federalism. This theory was developed to define how a governance approach for local public goods could secure innovation (Oates 1972). In essence, whether a uniform governance approach, as it might evolve under a centralized regulated approach, or a more decentralized governance approach can better facilitate innovation depends on two criteria: first, the heterogeneity of preferences for the provided good and second, the existence of economies of scale. The theory of fiscal federalism postulates that with increasing heterogeneity in preferences and low economies of scale a decentralized governance approach can better facilitate innovation (compared to a central approach), and vice versa.

In this paper, we apply the theory of fiscal federalism to the governance of information management and deliver indicators that support the hypothesis that both exist: heterogeneity in preferences for the provision of information management, and economies of scale. This leads us to the conclusion that neither a pure central nor a purely decentralized governance approach for information management is optimal. Rather, a certain degree of decentralization is required. We discuss two options to define the optimal degree of decentralization: Governmental decision and a market-based process. Due to information asymmetry between the government and the stakeholders involved in the information management system, the governmental decision on the size of the information management systems is not likely to result in

an optimal solution. Therefore, we argue that the government should define an institutional environment for information management (e.g. data security, privacy polices and standards) and then let market forces define the actual number of decentralized governance approaches (i.e. the degree of decentralization). As mentioned above, information management should facilitate the data exchange in smart grids to reduce the overall costs of RES integration of the distribution grid level. We build on this argumentation and discuss in greater detail under which conditions the decentralized governance approaches (defined by the market) will evolve around the operation areas of the distribution grid operators and can help to reduce the costs of RES integration. Our analysis shows that the network operator should to be able to incentivize the network users to join and actively participate an information management system to internalize externalities and avoid market failure. If this condition is met, then it is likely that the size of the governance approaches for information management will be linked to the operation areas of the distribution grid operators.

The paper is structured as follows: in section 2 we summarize the current literature and existing approaches for the governance of data management in smart grids. In section 3 we define information management as a club good and introduce the theory of fiscal federalism. Section 4 applies these theoretical insights to the case of information management in smart grids. Here we show for the case of information management that both heterogeneous preferences and economies of scale exist. Based on these results we discuss in section 5 under which conditions the market will define the optimal size of the governance approaches for information management. Section 6 concludes.

## **2 The current discussion and first approaches**

The current discussion in the context of the data exchange in smart grids strives to find an efficient institutional design to facilitate the information exchange. The

governance approaches under discussion should ensure neutrality and non-discrimination of third parties, i.e. a level playing field. The Smart Grid Task Force of the European Commission identified three concepts, two of which will result in regulated models, while the third one is a market-based approach. For the regulated models it is discussed to delegate the responsibility for data management either to the network operators (distribution grid operator (DSO) or the transmission system operators (TSO)) or an independent third party (Central Data Hub). Alternatively, market parties could provide the information management based on standardized processes (SGTF 2013). These models are subject of intense discussions. Among others, Ruester et al. (2013) and Lenstra et al. (2014) analyzed in more detail the future role of the DSO in the context of information management. While these studies focus on potential governance structures, they do not explicitly address the size of the information management system, i.e. the region covered by or users connected to an information management system. Neither do these studies focus on the relation between the size of an information management system and the level of innovation.

Still, each of the currently discussed concepts implicitly suggests certain specifications of the size of the information management system. For example, if a model is proposed that delegates the responsibility for information management to one single central third party, then there will be one information management per country or at least the region covered by this third party. On the other hand, if the DSO shall be responsible, then it is likely that the information management system will cover the same region (which represents the connected consumers and producers), as does the corresponding DSO.<sup>1</sup>

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<sup>1</sup> However, the size of the different DSOs in Europe differ significantly. While Germany has roughly 880 DSOs out of which 10% have a cumulated market share of more than 90%, Greece has only one DSO for the whole country. Additionally, it can be questioned whether the smaller DSOs with less than 100.000 costumers, (roughly 2350 out of the 2600 DSOs in Europe (CEER 2012)) will be able to bear the costs and the organization of information management. One solution to this problem could be that the larger DSOs might provide the information management infrastructure for the smaller DSOs as well.



So far, the current discussions in the context of the European Smart Grid Task Force focus on a uniform definition of a governance approach for information management, at least on the national level. Uniformity here refers to a central decision that one system approach is mandatory for all jurisdictions governed by the central authority, e.g. the EU. The downside of such a uniform approach, which applies one governance approach to all smart grid systems in a country or possibly even in the EU, is the potential missing link between a centralized approach and local requirements in the member states. The uniform approach is not able to adapt to local requirements. Therefore, in Brandstaett et al. (2017) we proposed an additional concept, which establishes neutrality, but does not require a uniform governance approach for information management. Our proposal focuses on a stakeholder-based decision approach, which should secure neutrality of data management. This concept has been labelled Common Information Platform (CIP). The CIP constitutes a common decision making body that could be responsible to decide which institution in a specific case should be responsible for data management. Thereby, the CIP is a solution to establish neutrality via the decision-making process and does not require adaptations in the institutional environment of smart grids. The basic idea of the CIP gets close to the concept of the Independent System Operator (ISO) (Balmert & Brunekreeft 2010). The ISO delegates the responsibility for the operation of a specific infrastructure (e.g. network operation) to an independent body while the ownership of the infrastructure can remain with another party (e.g. an integrated utility). This concept therefore is primarily discussed in the context of monopolistic infrastructures to avoid discrimination, which shall be secured by the ISO. Different from the ISO concept the CIP does not separate the ownership and operation of the respective infrastructure (electricity and telecommunication), but integrates all relevant parties into the decision making process to reduce risks of discrimination. Though we did not specify the size of the CIP so far, the idea of this concept is that it can be combined with decentralized as well as centralized concepts.

Irrespective of the open questions concerning the governance of information management in smart grids, some countries already took first steps to develop information management systems. These approaches can be sorted according to the size of each system, i.e. the number of the consumers connected to, or the area covered by the system. The current approaches can be allocated to three different categories of size:

1. Decentralized DSO models, e.g. in Spain each DSO has its own data base. This results in a very fragmented system with 350 independent data management systems (CEER 2012).
2. TSO centred models, as it is applied in Ontario, Canada. Here, the local Independent System Operator (ISO) of Ontario, named Independent Electricity System Operator (IESO), collects and manages the information of 4.8 million costumers (IESO 2012). Similar approaches can be found in Europe, e.g. in Denmark. However, as there is only one TSO in Denmark, this concept results in a national approach. In fact, most of the TSO centred models in the EU and neighbouring countries (Poland, Estonia, Norway) result in national models for information management, as in those countries that apply the TSO model only one TSO exists.
3. National models, e.g. the Netherlands applied a nationwide approach (which results in a variation of the Central Data Hub Model discussed in SGTF (2013)). The Data Hub is called Energy Data Services Netherlands, short EDSN, and is operated by the three largest Dutch DSOs. Similar to the Dutch case the model in Belgium is based on a central data clearing house (called ATRIAS), which is administered by the government (CEER 2012). In the UK the first official national data management and processing platform in Europe is currently developed. The approach in the UK is based on the Central Data Hub Model (SGTF 2013). The government assigned the responsibility for data

collection and processing to an independent service provider (DECC 2013). CEER (2012) stresses that the central approach in the UK creates a new monopoly, while a market based approach might have been possible as well.

The current academic debate, as well as the existing national initiatives for data handling in the electricity sector, point out that there is currently no clear framework to define an efficient size of an information management system in smart grids. With this paper we will shed some light on this issue.

### **3 Governance, innovation and the theory of fiscal federalism**

In section 1 we already stressed that the governance of information management should secure neutrality, non-discrimination and innovation. Especially the relevance of innovation was emphasized by CEER (2014), to point at the high uncertainty with respect to the future design of the electricity sector and the corresponding information management system. Due to this uncertainty it is important that the governance approach of information management facilitates innovations. Therefore, innovation here describes the ability of the governance approach of information management to adapt to the new developments in the context of smart grids. The question then is: Is there a relation between the size of an information management system (i.e. its governance) and the level of innovation incorporated by the governance approach of this system? This question has been addressed by the theory of fiscal federalism with respect to the provision of local public goods and we will apply this discussion to information management.

Fiscal federalism is a concept from public economics focusing on the efficient provision of (local) public goods. Tiebout (1956) defined local public goods as being non-rivalrous (until congestion arises) and excludable. Thereby, these goods are comparable to club goods, which Buchanan (1965) introduced as a solution for those public goods that offer the possibility to exclude consumers from it. Basically, we can think of a local public good being a club whose formation is based on geographical

criteria. Therefore, some analysis applied the club approach to local public goods (e.g. Casella 2001, Scotchmer (2002)).

Information management fulfils both criteria (non-rivalrous and excludable) of club and local public goods.<sup>2</sup> First, the services of information management can be defined as the non-rivalrous provision of equal access to data from different data sources for all eligible parties.<sup>3</sup> For the data we can assume that non-rivalry is given, as different parties can use the data at the same time. However, rivalry might result on the executive (or hardware) side of information management as soon as the demand for information exceeds the limitations of the system, e.g. with respect to hardware resources. Congestion could evolve if too many users are asking data from the information management system at the same time. Therefore, excludability is required to avoid congestion (i.e. crowding) in the information management.

Generally speaking, a club strives to balance cost-sharing gains from an increasing number of members and the potential losses associated with congestion or crowding (Sandler & Tschirhart ,1997). For example, a consumer that does not have a smart meter cannot provide the necessary information/data that is needed for services offered within smart grids. It seems reasonable to limit access to an information management club to those parties that deliver either information/data or services. Therefore, consumers who do not provide information might be excluded from the club. In addition, excludability is required to meet data security and privacy concerns

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<sup>2</sup> The attempt to define the service provided by information management as a club good is different from the current approach in the literature. So far scholars (e.g. Rüster et al. (2013)) focused on the data that is exchanged in information management systems and define the data as an information good. Rüster et al. (2013) specified that the data in smart grids is a digital information good (a concept introduced by Varian (1998)), which is non-rivalrous and at least partially non-excludable (depending on the technology and regulation applied). However, based on the digital-information-good approach it is difficult to define the nature of data in smart grids. This is due to the fact that at least the excludability-criterion of data depends on the institutional design of the information management.

<sup>3</sup> For a more detailed definition of information management in smart grids see Buchmann (2016).

by the information providers. At least for personal data it is necessary that each provider of information can restrict the access to this data (CEN 2012). Though excludability is given, there exist externalities that are not excludable. For example, if data exchange results in efficiency gains and reduces network investments, then all costumers can benefit from reduced network tariffs, irrespective of whether they are part of the information management or not. These externalities will be relevant for the analysis in section 5.

For local public goods and club goods (like information management) the theory of fiscal federalism analysis whether central or decentralized governance approaches better facilitate innovation.

Oates (1972) defines one of the core principles of fiscal federalism, the decentralization theorem. Basically, the theorem says that a decentralized governance approach for public outputs can increase welfare compared to a situation with a centralized 'one-size-fits-all' governance system, as long as economies of scale are not relevant (Oates 1972).<sup>4</sup>

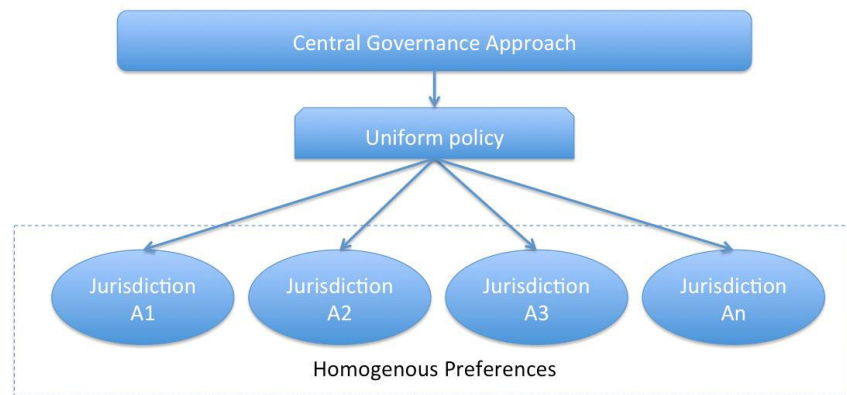
The decentralization theorem is based on two assumptions. First, it is assumed that the providers of the public good strive to optimize the welfare of the recipients, or that the governmental agent at least tries to reach reasonably efficient outcomes. Second, the decentralization theorem assumes that a central provision of local public goods results in a uniform provision for all regions under the central governance system. Oates (2008) provides two arguments that support his second assumption. From a political point of view, equity concerns might require a uniform provision of a

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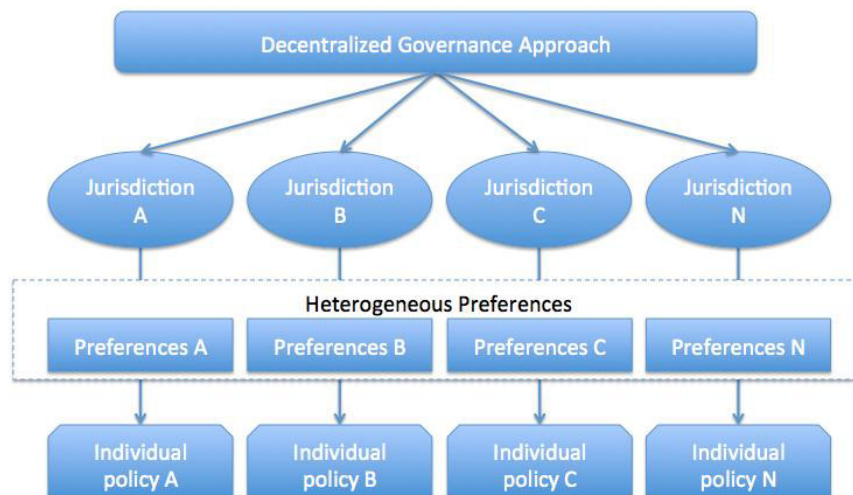
<sup>4</sup> Therefore, the decentralization theorem is very close to the subsidiary principle as it is defined in the Maastricht Treaty. However, the perceptive here is a bit different, as subsidiarity means that the lowest governmental level with the required resources should proceed with a public action. For further details see Oates (1999). A more detailed differentiation between fiscal federalism and the subsidiarity principle can be found in Bureau (1992)

good to avoid discrimination, even if this results in different costs for different regions. Strumpf & Oberholzer-Gee (2002) support this claim and stress that non-uniform policy approaches for different regions might result in local opposition from those regions that expect the most negative effects from the individual local policy. Furthermore, Oates argues that the transaction costs related to the central decision maker's effort to gain the relevant information about regional specifics are very high. Therefore, a central decision maker would always look for a uniform solution to minimize these transaction costs.

Summing up, there are several arguments that stress that a uniform policy is likely to evolve given a centralized governance approach. However, given heterogeneous preferences uniform policy approaches might result in less efficient outcomes than decentralized approaches.



(a) Central Governance with homogenous preferences



(b) Decentralized Governance with heterogeneous preferences

**Figure 2:** Central vs. Decentralized Governance Approaches

Oates (2008) provides examples from the environmental federalism discussion to prove the validity of the decentralization theorem (e.g. based on the analysis of Dinan (1999) on the drinking water regulation in the US).

Following Oates, these welfare losses could be avoided under a decentralized governance approach. He identifies two primary drivers for the cost advantages of decentralized governance systems. First, local demand for services and goods differ significantly between regions. Second, the costs to provide a service might differ between the regions as well. A decentralized governance approach could then better address these local specifications and thereby reduce costs compared to a uniform solution under a centralized governance approach.

The potential to foster innovation is discussed as another advantage of decentralized governance approaches. Bryce (1901) raised the idea that a decentralized approach allows to simultaneously develop different solutions and governance designs for the

same issue.<sup>5</sup> On the contrary, central governance approaches would only focus on one policy at a time. In the context of fiscal policy the decentralized governance approach is known as laboratory federalism (Oates 2008)<sup>6</sup>. Several different examples in the history of the US support the hypothesis of laboratory federalism, i.e. the potentially innovative effect of decentralized governance approaches. Taxation of gasoline, the introduction of an unemployment insurance and emission standards for cars were concepts developed by individual states and have later been adopted by the federal government (Oates 2008). More recently, several studies support the assumption that laboratory federalism results in higher economic income (For 20 OECD countries see Buser (2011), the US see Holcombe and Williams (2011) and Switzerland see Feld et al. (2004)). In addition, several studies provided evidence that local governments tend to copy successful policies from neighbouring jurisdictions, if these are applicable to the corresponding requirements (see for example Buettner (2001) for Germany, Schaltegger (2002) for Switzerland, Besley (1995) and Freeman (1985) for the US).

Strumpf (2002) provides theoretical support for the decentralization theorem, based on a model that focuses on strategic policymaking for the case of decentralized jurisdictions. Based on his model Strumpf (2002) concludes that decentralization results in a higher degree of innovation, if different policy options are available. Further empirical support for the decentralization theorem is provided by Strumpf & Oberholzer-Gee (2002). Their analysis is based on a panel dataset on the liquor control policy in the US (data from 1934 till 1970). Strumpf & Oberholzer-Gee (2002) conclude that the liquor policy in the US supports the central hypothesis of the

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<sup>5</sup> This is what Salmon (1987) denotes as horizontal competition and what is known as institutional competition (Siebert 1993)

<sup>6</sup> Which is a specification of the more general concept of economic federalism. Other forms of federalism are cooperative federalism (where the central government decisions are based on unanimity between the representatives of all jurisdictions) and democratic federalism (where the central government decisions are based on a majority from the representatives of all jurisdictions). For more details see Inman and Rubinfeld (1997)



decentralization theorem: heterogeneous preferences are best met with decentralized governance approaches and decentralized approaches set stronger incentives for innovation, as long as the regional preferences differ from each other.<sup>7</sup>

Summing up, the decision between centralized and decentralized governance approaches depends on the trade-off between heterogeneous preferences and economies of scale. With an increasing diversity of preferences decentralized governance approaches are superior of centralized approaches. *Visa versa*, if economies of scale are high, decentralized jurisdictions should merge to exploit these economies. The question in the context of fiscal federalism then is whether a decentralized governance approach does leave a potential for economies of scale unexploited, with the effect that the gains from decentralization (e.g. innovation) are outweighed by these additional costs from low economies of scale. Different studies (e.g. Feld et al. (2004) for Switzerland, Drew et al. (2014) for Australia) provide empirical insights revealing that unexploited economies of scale in a decentralized governance system do not necessarily result in a reduction of overall economic performance. We will investigate in the next section whether we can expect the same for the case of a decentralized governance approach of information management.

#### **4 Heterogeneity and economies of scale – implications for the governance of information management in smart grids**

As described above, the theory of fiscal federalism tells us that a decentralized governance approach can increase welfare (compared to a central governance approach), if the different regions have heterogeneous preferences. Specifically the level of innovation could be higher under decentralized governance approaches, given the assumption of heterogeneity. Furthermore, decentralized governance approaches are better capable of addressing local specifications, e.g. local preferences of the

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<sup>7</sup> This basic assumption is not without criticism. Among others, Rodden and Rose-Ackerman (1997) point at the risk that influential interest groups might be able to isolate decentral jurisdictions from external competition, which would in effect reduce innovation.

population. On the other hand, economies of scale are higher under a centralized approach. Therefore, the search for the optimal size of the governance approach for information management needs to start with the evaluation of preferences and economies of scale.

#### 4.1 Heterogeneous preferences

Our analysis in the following paragraphs shows that heterogeneous preferences exist with respect to information management. We illustrate this with an analysis of the situation in Germany. Still, the results obtained can be applied to other regions as well.

Importantly, our analysis focuses on the current situation in the German electricity system. It does not apply to the system as we know it from the last decades. Different from today's energy system, which has changed due to the diffusion of distributed generation, the electricity system (not only in Germany) was rather homogenous. A high level of standardization ensured an efficient operation of the system. Ten years ago, one would have concluded that preferences for the exchange of information were rather homogenous. Especially, as only a small group of actors were actively involved in the electricity supply chain, i.e. the market was highly concentrated. Therefore, a uniform governance approach, as it was actually applied, matched with these requirements quite well. However, this is changing with the development of smart grids (Brunekreeft et al, 2016).

We identify six arguments that support the assumption that the preferences in Germany with respect to information management in smart grids can be expected to be heterogeneous.

First, the technological decentralization of generation capacities is an important trend in the German (as well as other European) electricity system(s). Consumers start to

produce their own electricity based on RES and combined heat and power (CHP). Due to the regional differences in the availability of RES, especially for solar and wind energy, the differences in regional electricity systems are increasing. Based on these differences in RES, the regional requirements for the development of the electricity infrastructure and the resulting costs (see dena (2012) for details) differ as well.<sup>8</sup> Furthermore, the need for flexibility, on both the demand and the production side, might be higher in one region with a high share of RES than in those with lower RES.<sup>9</sup> Resulting from these differences on the technological level the requirement for the data exchange are likely to differ between these regions, too. While a region with low RES might require less extensive information management, other regions with high share of RES and/or high loads, e.g. from industry, might have a high demand for data exchange. Especially, if smart applications should substitute network investments and thereby increase overall system efficiency (BMW 2014).

Second, rural and urban areas differ with respect to their electricity system. For the case of Germany, especially rural areas face an increase in RES, while they are currently equipped with a less capable electricity infrastructure, i.e. networks. Urban areas, on the other hand, have a higher network capacity (due to high demand density) and a smaller share of RES installed (due to limited space). Due to these differences the requirement for smart grids is less significant in urban areas (high network capacity, low RES), while smart applications could help to reduce costs for RES integration into the rural networks (dena 2012).

Third, electricity consumers will soon be equipped with smart metering infrastructure. This metering infrastructure somehow needs to be connected to the

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<sup>8</sup> The difference between the regions in Germany have been identified in dena (2012) based on the analysis of twelve distribution grid operators with different network and supply characteristics. These network types differ significantly with respect to the installed capacities of RES and loads.

<sup>9</sup> The required per capita investment in the distribution networks to integrate RES will be six times higher in Mecklenburg-Western Pomerania than in North Rhine-Westphalia (dena 2012)

wide area networks to enable data exchange. Different technologies can be applied to establish this connection. Either cable based technologies (e.g. Power-Line-Communication (PLC) or Digital-Subscriber-Line (DSL)) or wireless technologies (General Packet Radio Service (GPRS) or Universal Mobile Telecommunications System (UMTS)) are possible. Which technology will be applied is context specific. In the case of Germany it is again possible to clearly distinct urban areas (with a high DSL and wireless coverage) and urban areas (with a low DSL and wireless coverage) (dena 2014).<sup>10</sup>

Fourth, regional electricity markets might evolve quite soon (triggered by RES expansion and the resulting need for flexibility). The concept of regional markets was introduced to allow local trade of balancing power or even local services specifically designed for the respective distribution grid. Batlle (2012) proposed to define local and physically connected balancing areas within the networks of the DSOs. These balancing areas should allow different retailers to provide flexibility services to both, the DSOs (e.g. for voltage control) and TSOs (e.g. frequency control). The assumption is that local approaches might make better use of potential for synergies than centralized systems (Ruester et al. 2013). Similarly, the requirements for data exchange will differ between these markets.

Fifth, the ownership structure in the electricity sector gets more heterogeneous as well (Brunekreeft et al 2016). While former investments in generation facilities were primary made by energy utilities or other companies, local cooperatives are today relevant investors for RES (e.g. roughly 12% of the US population is being served by energy cooperatives today (Yadoo 2010)) In Germany, more than 850 local cooperatives are active (Holstenkamp 2013). Furthermore, private investments in RES reached approximately 47% of all RES investments in 2012 in Germany (9%

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<sup>10</sup> PLC is based on the electricity networks and therefore has a high coverage rate in Germany. However, the current state of the technology seems not be sufficient for the data exchange from smart metering.

from cooperatives) (trendresearch 2013). Though renewable energy cooperatives evolve all over Germany, there are strong regional foci in specific regions. For example, Lower Saxony has the second highest number of energy cooperatives in Germany (Holstenkamp 2013). It is likely that in those regions, where cooperatives are active in electricity production from RES, the exchange and management of information will require a more active integration of regional actors into the governance process, as more people are actively participating in energy production.

Sixth, the regional preferences with respect to the consumption of green electricity differ significantly in Germany. While roughly 24% of all households in Bavaria had signed a green electricity contract in 2011, only 12% did so in Lower Saxony ((TNS 2011) and (preisvergleich 2014)). While these numbers do not show the regional preferences for information management in smart grids, they at least indicate that the interest in renewable energies and the willingness to transform this interest into a new contract with an alternative supplier differs significantly between regions. Whether similar heterogeneous preferences exist for information management in smart grids needs further investigation, but the experiences with green electricity contracts might serve as an indication for potentially diverse preferences.

These six arguments suggest that the requirements for information management and the demand for services based on this information will differ between regions in Germany. It might be possible that some regions require a very detailed data exchange due to technical reasons, while in other regions the local identification with electricity production from RES, e.g. based on cooperatives, requires a detailed stakeholder process to adapt the data exchange to local requirements. Furthermore, the demand for new services on the local level might differ as well, e.g. with respect to local balancing products. The governance of information management should address these differences.

## 4.2 Economies of scale

According to the theory of fiscal federalism, heterogeneity is a key driver for decentralized governance structures. On the other hand, with increasing economies of scale, the optimal governance structure becomes more centralized. The question then is whether economies of scale exist for the management of information in smart grids.

Following Silberston (1972) economies of scale can have different origins. First, initial fixed costs, which are independent from the scale, can be the source of significant economies. The management of information will require several investments for data collection, aggregation and distribution (trade), e.g. in data storage capacities, IT infrastructure etc. Therefore, fixed costs are likely to be high, while the variable costs of data exchange will be low (van den Oosterkamp 2014). The investment needs for information management are comparable to those currently made in the cloud-computing sector, which is a new market currently in the introduction phase. At least the storage capacities and the IT infrastructure to manage the exchange of data between the cloud and the user are comparable to the facilities required for information management in smart grids. The current market developments for cloud computing illustrate the potential for scale economies in the context of data storage and handling (Markovic 2013). Similar effects can be expected for information management with respect to fixed hardware costs. The example of cloud computing points at two other sources of economies of scale: the development of working capital<sup>11</sup>, e.g. from massed resources, and increased size. In the case of information management the mass resources can be larger server capacities and other parts of the IT infrastructure. With an increasing size of these server capacities the costs of the information management system might not increase proportionally with scale. Furthermore, the specialization of labour can increase scale

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<sup>11</sup> Noam (2009) here refers to technical economies of scale.

economies as well, e.g. specialist on data verification from smart metering can reduce operational costs.

Positive network effects can be a source for scale economies as well. Noam (2009) points out that due to network effects existing users gain from the integration of additional users, e.g. due to new demand or potential for cooperation. For information management network effects are likely to be important. For an established information management system the additional costs for the integration of a new data source or a new data user to an information management system is likely to be close to zero. At the same time the increase in output due to this new participant in the information management system might be huge (at least positive), as the new participant interacts with other parties in the system. One example can be the new service of aggregation, e.g. for the provision of virtual power plants. An aggregator of a virtual power plant combines different energy sources and sinks in its portfolio and sells the flexibility provided by this system to the market, e.g. to the balancing market. Integrating such an aggregator into the information management system comes at low costs. The aggregator increases cooperation between the different parties involved in the information management system, which might (significantly) increase the utility derived from the information management for all involved parties. For the case of the virtual power plant aggregator we can assume that the positive influence on the output of the information management system increases with its size, as the aggregator then gets access to more flexibility potentials. The described network effects therefore will have a positive effect with respect to economies of scale in the context of information management as well.

Additionally, economies of scope might exist for information management in smart grids. Different approaches might serve to develop these potentials. For example, not only data from electricity smart meters, but also other energy meters could be managed within one system. Furthermore, already today several registers with similar

data sets exist in the energy sector. It might be possible to combine these databases with the information management in smart grids to make use of the existing synergy potentials.

According to the theory of fiscal federalism the two previously discussed aspects of heterogeneous preferences and economies of scale are two important criteria that help to evaluate how the size of governance approaches can influence the level of innovation within the governed system. On the one hand, the analysis above revealed that for information management in smart grids economies of scale are relevant, which would favour a centralized governance approach to exhaust this potential. On the other hand, it seems likely that different regions in Germany are characterized by different preferences for the management of information in smart grids, e.g. with respect to the amount of data to be exchanged for the purpose of balancing etc. These heterogeneous preferences would rather support a decentralized approach to adapt the information management to the local specifications in favour of an optimal solution. Therefore, neither a purely centralized nor a purely decentralized approach seems to be an optimal solution for the governance of information management in smart grids, at least as far as fiscal federalism tells us. How can we find the optimal size then?

## **5 How to determine the optimal size for the governance of information management given heterogeneous preferences and economies of scale**

For the case of information management the analysis in section 4 of this paper revealed that the optimal size for the governance approaches requires a certain level of decentralization. The question then is how much decentralization is required. I.e. what is the optimal degree of decentralization?

We discuss two options how the number of decentralized governance approaches for information management can be defined: Either via governmental decision or based



on market forces. First, the government could define the number of governance approaches and the areas these approaches should cover. This is actually how it is done in most European states at the moment. However, in most cases the governments defined central, and thereby uniform, governance approaches. We have introduced these examples for central and uniform governance approaches already in section 2 (e.g. Denmark and other countries delegated the task of information management to the TSOs, which results in a central model, UK operators a national monopoly etc.). This observation supports the decentralization theorem, as it was introduced in section 3: Governments tend to apply uniform governance approaches, neglecting heterogeneous preferences.

For now, let us assume that a central government strives to define a decentralized governance design for information management (that is, we neglect the insights from fiscal federalism for now).<sup>12</sup> In this case, the problem is that the government does not have the information about the heterogeneous preferences of all relevant stakeholders (or it would result in very high transaction costs to gather all the information, which potentially will exceed the benefits derived from the additional information). Due to information asymmetry between the government and the network users, the governmental decision on the size of the decentralized approaches is not likely to be optimal. As an alternative to the governmental decision, information asymmetry can be addressed by a market-based approach. This is the second option we want to discuss.

Instead of a governmental decision to define the size of the governance for information management systems, the government could just define the higher-level institutional framework for the governance of information management (like

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<sup>12</sup> In this scenario, with regional information management systems implemented by the government, the different governance approaches can still compete with or learn from each other. Such a system would get close to a system of institutional competition. Under these circumstances concepts like sunshine regulation (McKraw 1984) could be applied to secure that efficiency potentials on the decentralized level are exploited (at least to a certain extent).

standards, privacy issues etc.) and let market forces define the optimal degree of decentralization. Given this scenario, we can expect that there will evolve different governance approaches for information management that address different needs on the decentralized level. Each user will be free to choose which information management system (and thereby which governance approach) he wants to join. Thereby, each user will decide to join a specific information management system based on an individual cost-benefit analysis. In other words, the stakeholders will decide which club for information management they want to join. Furthermore, each decentralized information management system will decide within its governance approach which users and how many of them can join their system (i.e. the information management club). Buchanan (1965) illustrated that the optimal size of the clubs is defined by the costs and benefits from sharing a resource. I.e. the costs for having an additional consumer must equal the average costs required for the provision of the respective good (Casella 1992). This cost-benefit evaluation will be done by the individual governance system for information management, which should (according to Buchanan (1965)) result in optimal solutions for the size of the clubs.

Given the second option, a market-based approach to define the optimal size of the decentralized governance approaches for information management, it might happen that either a very fragmented or very concentrated landscape of decentralized governance approaches evolves. However, we think that the size of the governance approaches for information management will (and should) be linked to the balancing areas on the distribution grid, i.e. the area covered by a distribution grid operator. In section 4 we introduced six indicators that describe the heterogeneous preferences with respect to information management in Germany. Out of these, the regional differences in RES and the resulting requirement for flexibility and network investments is very important in the given context of smart grids. Recall that the primary purpose of smart grids is the efficient and flexible local balancing of demand and supply (especially from RES) to reduce the requirement for grid investments.

Therefore, the different services anticipated to evolve in smart grids focus on a local/regional scale (SGTF 2010). The exchange of data between different regions that are not connected on the distribution grid level is therefore not a necessary requirement for smart grids. Though there might evolve other requirements for interregional data exchange in smart grids, the primary task of an information management system in smart grids is to ensure efficiency on the local level.<sup>13</sup> Importantly, this does not imply that the DSO necessarily is in charge of the information management system. Rather, the DSO is one important stakeholder for the governance of an information management system (Brandstaett et al, 2017).

We argue that under a market-based approach, where users can freely choose their governance system, the size of the information management systems and their decentralized governance approaches will evolve to the network areas of the DSOs under one important condition: The network operator needs to be able to *incentivize* network users to actively participate in an information management system.

This condition needs to be met to address the externalities related to information management systems. In section 3 we discussed that information management will result in such externalities. Among these externalities are reduced network charges, which can result from efficiency gains and reduced network investments based on the data exchange in the information management system. If different network users interact with the DSO via the information management to efficiently manage the distribution grid, then these actions should reduce the overall network costs. Now, if these reduced costs result in an overall reduction of the network charges for *all* network users, then this is an externality. In this case, the externality motivates free-riding. To illustrate this, think of a network operator who exchanges data with some network users via an information management system. Based on the data available some network users are asked to adapt their consumption or production according to

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<sup>13</sup> Importantly, the exchange of information with the TSOs needs to be secured.

the network operator's requirements. This will result in costs for the network users that react to network operators demand. The network users adaption of consumption and/or production of electricity should increase efficiency (in network operation) and therefore should result in reduced network operation costs. Now, these benefits are socialized via the overall network charges. I.e. the network charges for *all* network users, and not only those who bore the costs, are reduced. Next, let's assume that the network users might have other incentives (e.g. derived from a specific service only available in one information management system) to join an information management system that does not include the regional DSO to which they are physically connected. Under this assumption the network user would still gain from the externalities accomplished by the information management system that involves the local DSO (via the reduced network charges), without being a member of that system and bearing its costs. Under this assumption, the market will not provide the necessary service of information management, which is a market failure. One option to address this market failure could be governmental intervention (regulation). As discussed before in this section, this governmental solution is not likely to result in an optimal solution.

The situation changes if the network operator is able to incentivize the relevant network users to join the same information management. This incentive is required for the coordination between the network operator and the network user via the information management system. The goal of this coordination is the reduction of the network operation costs. Several studies revealed the potential to reduce the costs of RES diffusion based on to the active integration of network users as providers of flexibility for the network operation.<sup>14</sup>To unlock the efficiency potential related to the flexibility provision by network users data needs to be exchanged between the network users and the network operators (Brandstaett et al 2011). This data exchange should be facilitated by the information management system. Based on the data

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<sup>14</sup> for Germany see dena (2012) and BMWi (2014), more general for Europe see SGTF (2015)

available in the information management system the network operator should be able to offer incentives (e.g. in form of payments) to the participants to adapt their consumption or production of electricity according to the network operators needs. It is reasonable that the network operator financially rewards the users adaptation to the networks requirement, as the adaptation of the user (at least) avoids additional costs for all users for the network integration of RES. Obviously, the network operator should only incentivize flexibility that has lower cost than network expansion. The information management system provides the basis for the network operator and the network users to exchange data and incentives (e.g. via a regional market). This implies that both the network operator and the network user need to be physically connected and part of the same information management system to be able to exchange information, incentives and flexibility (i.e. electricity production or consumption, demand side management etc.).

Under the assumption that the network operators can offer incentives to the network users being part of the same information management system, it seems reasonable to expect that the decentralized governance systems for information management will somehow (driven by the market) evolve around the DSOs. Nevertheless, network users would still be free to choose which information management system they want to join. Different information management systems with different governance approaches can compete on the decentralized level. This competition should increase efficiency. But, under the assumptions described above, the DSO will be able to incentivize those network users that offer a relevant flexibility potential (and thereby the potential for cost reduction) and are connected to the DSOs grid, to join the same information management system(s) as does the DSO.

Under these conditions it might turn out that for each network area owned by a single DSO an individually governed information management will be applied. However, it is possible as well that an information management covers more than one DSO, if the

preferences for the information management system are similar (homogenous) in the network areas of the different DSOs. Then economies of scale can be exploited as well.

If the DSO is not able to incentivize the participation of its network users in the same information management system, then the size of the decentralized governance approaches defined by the market can still be optimal (if no market failure occurs), but will not necessarily be related to the service areas of the DSOs and might not serve the development of smart grids.

## **6 Conclusion**

In this paper we analyzed how we can define the optimal size of an information management system in smart grids. Information management here refers to the collection, aggregation and distribution of data (e.g. from smart metering). The governance of information management needs to secure neutrality, non-discrimination and innovation. Our analysis shows that the size of the governance approach for information management can have an influence on innovation within the information management system.

As a basis, we illustrate that information management can be defined as a club good and apply the theory of fiscal federalism. This theory addresses the question under which circumstances a decentralized or centralized governance approach results in higher levels of innovation. To determine which governance approach could be applied in a given context one needs to evaluate the heterogeneity of preferences between regions and potentials for economies of scale.

We focus our analysis on the case of Germany to show how the theory of fiscal federalism can be applied to define the size of a governance approach for information

management in smart grids. Based on these insights we find that both exist, heterogeneous preferences and economies of scale. Therefore, neither a central nor a purely decentralized governance approach will result in an optimal size.

The heterogeneous preferences suggest a decentralized governance approach to adapt the information management to local specifics. Therefore, our analysis results in the recommendation not to apply central governance approaches to information management in smart grids. Still, there exist potentials for economies of scale as well, which will not be exploited given a purely decentralized governance design.

We discuss two options how the size of the governance approaches on the decentralized level could evolve. First, the government could define the size of the decentralized governance approaches. This is unlikely to result in optimal solutions due to the information asymmetry between the government and the users of the information management. This information asymmetry will either result in high transaction costs to gain the required information or leave efficiency potentials unexploited. Furthermore, it was discussed in this paper that governments tend to apply central and uniform governance approaches, which will reduce innovation and efficiency given heterogeneous preferences. The second option to define the size of the decentralized governance approaches is a market-based approach. Here, the government defines the high-level institutional environment (e.g. standards, privacy policies etc.), and given this environment market-forces should define the optimal size of the governance approaches. For the market-based approach we point out that the network operator should be able to incentivize the network users to join and actively participate in the information management system, if the network users interaction with the DSO via the information management system increases efficiency (i.e. reduces the costs of network operation). It is necessary that the DSO can incentivize the participation and interaction in the information management

system to avoid free-riding based on the externalities of the information management system (e.g. reduces network charges for all network users).

Provided that the DSO can incentivize the network users to join and actively participate in the information management system, we conclude that economies of scale might be exploited as well, if an information management system covers more than just one DSO and its network area.

## References

- Andrews, R., Boyne, G. A. 2009, 'Size, structure and administrative overheads: An empirical analysis of English local authorities', *Urban Studies* **46**, 739-759.
- Battle, C. Rivier, M. 2012, 'Identifying the new role and procedures of power network operators for an efficient exploitation of distributed energy resources.', *IIT Working Paper University Pontificia Comillas* .
- Besley, T. Case, A. 1995, 'Incumbent behavior - vote-seeking, tax-setting, and yardstick competition', *American Economic Review* **85**(1), 25–45.
- BMWi. 2014, *Distribution Grid Study*, Berlin
- Borras, S. Jacobsson, K. 2004 , 'The open method of coordination and new governance patterns in the EU', *Journal of European Public Policy* **11**(2), 185–208.
- Brandstaett, C. Buchmann, M. Brunekreeft, G. Friedrichsen, N. 2017, Balancing between competition and coordination in smart grids – a Common Information Platform (CIP)', *Energy Economics and Environmental Policy* **6** (1)
- Brandstaett, C. Brunekreeft, G. Friedrichsen, N. 2011, Locational signals to reduce network investments in smart distribution grids: What works and what not?', *Utilities Policy* **19** 244-254.
- Bryce, J. 1901, *The American Commonwealth*, Macmillan.



- Brunekreeft, G. Buchmann, M. Meyer, R. 2016, 'The rise of third parties and the fall of incumbents driven by large-scale integration of renewable energies: the case of Germany', *Energy Journal* **37** (SI2), 243 - 265
- Brunekreeft, G. Buchmann, M. Meyer, R. 2016, 'New Developments in Electricity Markets Following Large-scale Integration of Renewable Energy', In: Finger, M. Jaag, C. 2016, *The Routledge Companion to Network Industries*
- Buchanan, J. 1965, 'An economic-theory of clubs', *Economica* **32**(125), 1–14.
- Buchmann, M. 2016, 'Who Should Govern Information Management to Balance Between Coordination and Competition on the Distribution Grid Level? ', *Bremen Energy Working Papers No. 22*.
- Buettner, T. 2001, 'Local business taxation and competition for capital: the choice of the tax rate', *Regional Science and Urban Economics* **31**(2-3), 215–245. Conference on Fiscal Competition and Federalism in Europe, Zentrum Europa Wirtschaftsforschung, Mannheim, Germany, Jun 02-03, 1999.
- Bureau, D. Champsaur, P. 1992 , 'Fiscal federalism and european economic unification', *American Economic Review* **82**(2), 88–92. 104TH Annual Meeting of the American Economic Accoc., New Orleans, LA, Jan 03-05, 1992.
- Buser, W. 2011, 'The impact of fiscal decentralization on economics performance in high-income OECD nations: an institutional approach', *Public Choice* **149** (1-2), 31-41.
- Casella, A. 2001, 'The role of market size in the formation of jurisdictions', *Review of Economic Studies* **68**(1), 83–108.
- Casella, A. Frey, B. 1992, 'Fiscal federalism and the theory of clubs - towards an economic theory of overlapping political jurisdictions', *European Economic Review* **36**, 639–646.
- CEER 2012, Benchmarking report on meter data management, Technical report, Council of European Energy Regulators.
- CEER 2014, Draft advice on data management for better retail market functioning electricity and gas, Technical report, Council of European Energy Regulators.

- CEN-CENELEC-ETSI 2012, Smart grid coordination group smart grid information security, Technical report.
- DECC 2013, The smart metering system, Technical report, Department of Energy and Climate Change.
- dena 2012, Distribution grid study, Technical report, Deutsche Energie-Agentur GmbH (dena).
- dena 2014, Smart Meter Study, Deutsche Energie-Agentur GmbH (dena).
- Desmarais-Tremblay, M. 2014, 'On the definition of public goods - assessing richard a. musgrave's contribution', *CER Working Papers - Documents de Travail du Centre d'Economie de la Sorbonne* .
- Dinan, T. M., Cropper, M. L. Portney, P. R. 1999, 'Environmental federalism: Welfare losses from uniform national drinking standards.', *Environmental and Public Economics* pp. 13–31.
- Drew, J., Kortt, M.A., Dollery, B. 2014, 'Economies of Scale and Local Government Expenditure: Evidence From Australia', *Administration & Society* **46**(6), 632-653.
- Feld, L.P., Kirchgässner, G., Schaltegger, C.A. 2004, 'Fiscal Federalism and Economic Performance: Evidence from Swiss Cantons', *Volkswirtschaftliche Beiträge Marburg*, 20/2004.
- Freeman, P. 1985, 'Interstate communication among state legislators regarding energy-policy innovation', *Publis - The Journal of Federalism* **15**(4), 99–111.
- Friedrichsen, N., Brandstaett, C. , Brunekreeft, G. 2013, 'The need for more flexibility in the regulation of smart grids – stakeholder involvement', *International Economics and Economic Policy* **10**.
- Holcombe, R.G., Williams D.W. 2011, 'The cartelization of local governments', *Public Choice* **149**, 65-74.
- Holstenkamp, L. Mueller, J. 2013, 'On the state of energy cooperatives in germany on the state of energy cooperatives in germany - a statistical overview as of 31

- december 2012’, *Working Paper Series in Business and Law - Leuphania University* (14).
- IESO 2012, Building privacy into ontario’s smart meter data management system: A control framework, Technical report, Independent Electricity System Operator Ontario.
- Lenstra, J., van Hussen, K., Haffner, R., van den Oosterkamp, P., Koutstaal, P., van der Welle, A. de Joode, J. 2014, Draft final report “The role of DSOs in a smart grid environment”, Amsterdam/Rotterdam
- 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.
- Marques, R.C., Simoes P. 2008, Does the sunshine regulatory approach work? Governance and regulation model of the urban waste services in Portugal’, *Resources, Conservation and Recycling* **52**, 1040-1049.
- McCraw K. 1984, *Prophets of regulation: Charles Francis Adams, Louis D. Brandeis, James M. Landis and Alfred E. Kahn*, Harvard University Press Cambridge, USA.
- Mueller, D. 2006, *Democratic constitutional design and public policy: analysis and evidence*, MIT Press, Cambridge, Mass., chapter Federalism: A Constitutional Perspective, pp. 205–228.
- Noam, E. 2009, *Media Ownership and Concentration in America*, Oxford University Press.
- Oates, W. 1999, ‘An essay on fiscal federalism’, *Journal of Economic Literature* **37**(3), 1120–1149.
- Oates, W. E. 1972, *Fiscal Federalism*, Harcourt Brace Jovanovich.
- Oates, W. E. 2008, ‘On the evolution of fiscal federalism: Theory and institutions’, *National Tax Journal* **61**(2), 313–334.
- preisvergleich.de 2011, ‘Ökostrom studie 2011’.  
<http://www.preisvergleich.de/strom/info/oekostrom-studie-2011-183/>

- Radaelli, C. 2003, The open method of coordination: A new governance architecture for the european union, Rapport 1, Swedish Institute for European Policy Studies.
- Rodden, J., Rose-Ackerman S. 1997, 'Does Federalism Preserve Markets', *Virginia Law Review* **83**, 1521-1572.
- 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.
- Salmon, P. 1987, 'Decentralization as an incentive scheme', *Oxford Review of Economic Policy* **3**(2), 24–43.
- Sandler, T. Tschirhart, J. 1997 , 'Club theory: Thirty years later', *Public Choice* **93**(3-4), 335–355.
- Schaltegger, C. Kuttel, D. 2002, 'Exit, voice, and mimicking behavior: Evidence from Swiss cantons', *Public Choice* **113**(1-2), 1–23.
- Scharpf, F.W. 1988, 'The Joint-Decision Trap: Lessons from German Federalism and European Integration', *Public Administration* **66**, 239-278.
- Schelling, T. 1969, 'Models of segregation', *American Economic Review* **59**(2), 488–493.
- Scotchmer, S. 2002, 'Local Public Goods and Clubs', In: Auerbach A. and Feldstein M., 'Handbook of Public Economics', Vol IV, North Holland Press.
- SGTF 2010, Functionalities of smart grids and smart meters, Technical report, EU Commission Task Force for Smart Grids - Expert Group 1.
- SGTF 2013, Eg3 first year report: Options on handling smart grids data, Technical report, EU Commission Task Force for Smart Grids - Expert Group 3.
- SGTF 2015, Regulatory Recommendations for the Deployment of Flexibility, EU Commission Task Force for Smart Grids - Expert Group 3.
- Strumpf, K. 2002, 'Does government decentralization increase policy innovation', *Journal of Public Economic Theory* **4**(2), 207.

- Strumpf, K. Oberholzer-Gee, F. 2002, 'Endogenous policy decentralization: Testing the central tenet of economic federalism', *Journal of Political Economy* **110**(1), 1–36.
- Tiebout, C. 1956, 'A pure theory of local expenditure', *Journal of Political Economy* **64**(5), 416–424.
- TNS-Infratest 2011, Anteil der Haushalte mit Ökostrombezug in Deutschland nach Bundesland im Jahr 2011, Technical report, Agentur für Erneuerbare Energien.
- trend:research 2013, Definition und Marktanalyse von Bürgerenergie in Deutschland, Technical report, Initiative "Die Wende – Energie in Bürgerhand" and Agentur für Erneuerbare Energien.
- Varian, H. R. 1998, 'Markets for information goods', *University of California, Berkeley*.
- Vasirani, M. Ossowski, S. 2013, 'Smart consumer load balancing: state of the art and an empirical evaluation in the Spanish electricity market', *Artificial Intelligence Review* **39**(1, SI), 81–95.
- Wittman, D. 1989, 'Why democracies produce efficient results', *Journal of Political Economy* **97**(6), 1395–1424.
- Yadoo, A. Cruickshank, H. 2010, 'The value of cooperatives in rural electrification', *Energy Policy* **38**(6), 2941 – 2947.