Energy Research & Social Science 74 (2021) 101974

Contents lists available at ScienceDirect

Energy Research & Social Science

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

Original research article

Smart grids and institutional change: Emerging contestations between organisations over smart energy transitions

Friederike Rohde [a,b,*], Sabine Hielscher [b,c]

[a] Institute for Ecological Economy Research (IÖW), Potsdamer Strasse 105, D-10785 Berlin, Germany
[b] Center for Technology and Society (ZTG), Technische Universität Berlin, Sekr. KAI 3-2, Kaiserin-Augusta-Allee 105, D-10553 Berlin, Germany
[c] Science Policy Research Unit (SPRU), School of Business, Management, and Economics, University of Sussex, United Kingdom

ARTICLE INFO

Keywords:
Smart grids
Organisations
Institutional change
Issue-based field
Institutional work

ABSTRACT

Smart grids are promoted as promising pathways for dealing with new grid challenges that have arisen by the introduction of renewable energies. In Germany, increasing shares of volatile renewables have led to a growing number of smart grid pilot projects and related regulatory and market developments. Even though, much has been done to develop the smart grid, significant difficulties remain, in particular, the re-negotiation of new roles and responsibilities of the organisational actors involved. From a sociological perspective, these shifts imply changes to current institutional arrangements within energy systems. Drawing on new organisational institutionalism and a qualitative analysis of German smart grid developments, this paper sheds light on organisations' differing practices aimed at creating, maintaining and disrupting institutions (i.e. institutional work). First, we show how organisations' existing roles, rules, norms, and beliefs are being challenged (or not) through the rise of smart grid technologies and what contestations have arisen within the smart grid field. Second, we analyse how organisations attempt to influence institutional changes and identify five different forms of institutional work conducted by actors in the German smart grid field. The paper demonstrates how organisations within smart grid developments attempt to reconfigure institutional arrangements in diverging or even contradictory ways. The paper reveals how the re-institutionalisation processes related to smart grids require fundamental changes in the common meaning system. Implementing these changes will remain a challenge if actors try to maintain existing institutional arrangements.

1. Introduction

The German 'Energiewende' (sometimes called 'energy turnaround') has led to the need of integrating fluctuating renewable energies into the German electricty grid. As part of these developments, high expectations have been expressed when implementing smart grid technologies to match renewable energy supply and demand. The basic idea of a smart grid 'amounts to coupling the electricity delivery infrastructure with modern telecommunications and sending technology (…) the real promise of the smart grid is the ability to process and analyse large amounts of information' [1, p. 61] to cope with the future energy supply challenges [2] and create a more sustainable energy system [e.g. 3]. Advocates consider smart grids as a solution for 'almost every thinkable energy issue' [4] but there is lack of a shared vision [5] and common definition [6]. In addition to offering technological opportunities to integrate fluctuating renewable energy, smart grids are said to solve a wide range of social challenges [7], such as enabling new practices of flexible energy consumption [8]. As argued by Lösch and Schneider, future smart grid developments require substantial changes to existing relationships, constellations and interactions of all actors [9]. Smart grid developments are referred to as all activities aimed at testing, demonstrating and implementing smart grids. These developments profoundly challenge incumbent paradigms and patterns of thought within the current energy system [10]. It is the existing institutional order that is challenged and becomes the subject of ongoing negotiations between actors in smart grid developments. For example, the shift from centralised actors and structures to local self-organising structures implies a fundamental change in common meaning systems. This paper aims to gain a better understanding of how smart grid developments challenge existing institutional arrangements. Conceptually, our work is based on organisational institutionalism, which is a sociological perspective on institutions with a particular emphasis on organisations. We aim to show

* Corresponding author at: Institute for Ecological Economy Research (IÖW), Potsdamer Strasse 105, D-10785 Berlin, Germany.
E-mail address: friederike.rohde@ioew.de (F. Rohde).

https://doi.org/10.1016/j.erss.2021.101974
Received 9 July 2020; Received in revised form 29 January 2021; Accepted 3 February 2021
Available online 23 February 2021

how organisations involved in German smart grid developments engage in 'institutional work' i.e. trying to actively shape the respective institutional changes so that they can take up their preferred roles and responsibilities. Their endeavours have led to a multiplicity of aims, interests and belief systems linked to smart grid developments that currently exist alongside each other. In our analyses, we focus on the overarching contestations and forms of institutional work that occur within the German smart grid field, of which pilot projects are an important part.

Although the key roles of institutions have been acknowledged in energy system transformations (e.g. sustainability transitions have conceptually been founded on institutional theory) [11], this conceptual framing has been under-utilised for some time [12]. Several scholars have indicated the relevance of changing institutional structures for the development of smart grids, or more generally smart energy systems [13–15] and called for institutional theory to be brought into discussions on low-carbon-energy transitions [e.g. 16,17]. Recently institutional theory and new institutionalism have received considerable attention for the way in which they conceptualise socio-technical dynamics in energy transitions [18], and there is a growing body of literature applying institutional theory to energy transitions [e.g., 16] or the adoption of smart technologies such as smart meters [19]. Since smart grids consist of diverse layers of socio-cultural processes and organisations, all stakeholders, from energy suppliers to households, have to undergo fundamental changes. These changes do not only have to do with their role but also their routine practice and beliefs about how energy should be produced, transported and consumed. Consumers are turning into prosumers, transmission system operators have to coordinate flexible energy production, and energy suppliers have to introduce new ways to incentivise flexible energy demand practices. As part of these on-going transformations, actors alter their current positions and deal with conflicting interests [20].

Crucial to implementing smart grids is the establishment of common rules about how the activities and responsibilities of existing and emerging organisations (such as IT-developers and start-ups) can be coordinated within a highly heterogeneous field (i.e. the smart grid field consists of, for instance, energy suppliers, transmission and distribution system operators, energy consumers, aggregators, and ICT/software and hardware providers). Efforts to establish such rules have been subject to contestations due to diverse interests, opportunities to benefit (or not) and different organisational cultures (e.g. start-ups versus large established organisations).

This paper sheds light on the institutional change processes linked to German smart grid developments in two ways. First, we analyse relevant contestations within the smart grid field, and investigate how actors' existing practices linked to their roles, norms and beliefs are challenged (or not) through introducing smart grids. Second, we examine how actors attempt to influence and/or steer these institutional changes. Conceptually, we draw on new institutionalism to examine the institutional changes linked to smart grid developments. In particular, we make use of the following three concepts: organisational field [21], or more specifically issue-based field [22], pillars of institutions [23] and institutional work [24]. These concepts help to develop an understanding of how the institutional order (i.e. institutionalised rules, roles and belief systems) is being challenged through current smart grid developments, and how organisations are attempting to influence efforts to advance smart grid deployments.

We address the following research question:

> What challenges do organisations involved in smart grid developments currently face and how do they attempt to engage in processes of institutional change?

We focus our analysis on the contestations between organisations, specifically formal, complex or large-scale organisations, which are defined as social units characterised by a planned order and goal-oriented activities [25]. When we talk about actors and actions, we refer to collectively organised actions taking place in and/or between organisations and do not focus on individual users and their roles within smart grid developments [4,25–27]. The remainder of this paper is structured as follows: Section 2 provides information on smart grid developments in Germany and situates the paper in the academic literature on smart grids. It is followed by an outline of the conceptual framework (Section 3) and a description of the methodological approach (Section 4). Section 5 presents the findings, including the relevant organisational actors and core contestations between them within the smart grid field in Germany. Section 6 discusses the different forms of institutional work identified and their relevance for smart grid developments. In conclusion, we consider why the introduction of smart grids has not met initial expectations.

2. Background: Smart grid developments in Germany and the role of institutions

The growing penetrations of renewable and distributed energy resources pose significant challenges for the stability, efficiency and reliability of existing energy system operations [29]. In Germany, the share of renewable energy in electricity production increased from 8.6% in 2002 to 50.5% in 2020[1]. Consequently, since 2008, the implementation of smart grids has become one of the main issues in energy policy developments and funding programmes in Germany. The first initiative to support smart grids was a funding program called 'E-Energy - ICT-based energy system of the future' launched by the Federal Ministry of Economics and Energy (BMWi) in partnership with the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). Between 2008 and 2013, six smart grid pilot projects were initiated to establish several smart grid model regions and develop recommendations for a smart grid roadmap. In 2011, the German Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway (Bundesnetzagentur) led an attempt to define smart grids and introduced a distinction between smart grids (i.e. aspects related to network capacity) and the smart market (i.e. aspects related to amounts of energy) [30]. The German Federal Association of the Energy and Water Industry (BDEW) defined a smart grid as,

> 'An energy network, which integrates the consumption and feed-in behaviour of all market participants connected to it. It represents an economically efficient, sustainable production system that has the aim to create low level losses and high availabilities '[own translation] [31, p. 12].

In 2014 and 2015, a 'Weißbuch' (white book) and 'Grünbuch' (green book) called 'Ein Strommarkt für die Energiewende' (an electricity market for the energy turnaround) was set in motion. All interested stakeholders were able to formulate position statements linked to possible changes to the electricity market design, capacity reserve solutions and/or balancing responsibilities. In 2016, the BMWi funded four regions within the SINTEG – 'Schaufenster intelligente Energie' (showcase intelligent energy) funding programme and created a temporary regulation environment that allowed for 'experimentation possibilities'. These opportunities offered SINTEG participants to practically test new network operation concepts, technologies, processes and business models. Another key step was the law on the digitalisation of the Energiewende (LDW), which has predominantly regulated the rollout of intelligent measurement systems (i.e. smart meters and related communication infrastructures, such as smart meter gateways). Intelligent measurement systems are an important technological premise for facilitating bi-directional information flow within the electricity system

[1] https://energy-charts.info/charts/renewable_share/chart.htm?l=de&c=DE (Access: 15.01.2021).

[32]. Beyond these technological challenges, the 'Barometer Digitalisierung der Energiewende' (barometer digitalisation of the energy turnaround) in 2018 identified 'adherence to traditional structures and working methods' as a reason for the poor progress in smart grids developments [32, p. 67]. The latest report stated that the 'involved actors should overcome thinking and working in silos' [33, p. 57].

The development of smart grids is not only a technological endeavour but also a social one [35]. Energy supply systems are highly institutionalised, 'they are full of regulations, norms, and socially and culturally defined patterns of thinking' [36, p. 824], which are potentially deeply challenged through smart grid developments. New standards and regulations need to be developed, policies and market mechanisms have to be adjusted, novel technologies require maturing [37] and existing actors' roles are being redefined within these developments. Reviewing smart grid projects across Europe, Gangale et al. [29] have suggested that the distributions system operators (DSOs) will have to take a more active role in managing and operating their networks in order to improve the efficiency, reliability and security of networks through smart grid technologies. Grid operators are increasingly forced to conduct measures to redispatch and balance the grid. Other organisations, such as technology manufacturers and information and communication technology developers, have become increasingly interested in creating smart grid technologies for the energy sector, bringing in novel technologies and business models [14,29]. Existing demands and expectations from a diverse set of actors draw attention to the fact that smart grid developments are subject to societal negotiations processes in which actors bring their own interests to the table [38]. The necessary coordination requirements between heterogenous organisations and institutional changes that are part of these negotiation processes pose huge challenges to the organisations involved [7,38]. These changes include, for example, a paradigm shift from centralised structures and markets to decentralised, regional and local self-organising structures [10].

So far, some of the social science research on energy transitions [e.g. 14] has highlighted the key role of institutions within smart grid developments [e.g. 2,36] and has argued that 'the study of institutions must therefore form a key component of analysis and policy formulation'[16, p. 223]. Scholars have investigated the roles of particular groups of actors such as new entrants [14], incumbent utilities [39] and the smart grid industry [5]. Other research has focused on issues of trust and confidence [40] to build actors' relations and stressed the importance of collaborations between actors [41]. Andrews-Speed [16] has argued for a broader institutional perspective that pays attention to political and economic systems, which determine the pace and path of energy transitions in a particular country. Institutional theory has also been applied to compare low-carbon energy system transformations across countries [18]. Fuenfschilling and Truffer [15] have provided some conceptual foundations for explaining levels of structuration of socio-technical systems as 'degrees of institutionalisation' and make use of the notion of 'institutional logics' to understand how structures become established in energy transitions [42]. With this paper, we strengthen the recent 'rediscovery' of institutional theory [13,16,18] for explaining change processes linked to smart grid developments.

Although there have been some attempts to overcome these challenges in Germany, in depth analyses of the reconfigurations and contestations between organisations that occur within smart grid developments are still largely under-researched [43]. Up to this point, little research has gone into looking more closely at the forms of 'institutional work' actors engage in and how they shape the course of institutional changes. We address this gap by shedding light on the institutional change processes linked to German smart grid developments in two ways. First, by showing how actors' existing practices, roles and beliefs are challenged (or not) through the introduction of smart grid technologies. Second, we reveal how actors attempt to influence and/or steer institutional changes. Drawing on new institutionalism and examining smart grid pilot projects makes it possible to study the processes of institutional change (including negotiations between organisations) and practices of institutional work (including the ways in which actors maintain, disrupt and create institutions).

3. Conceptual Framework: Investigating institutional changes

Smart grid developments call for a change of existing institutions and institutional arrangements (i.e. overarching rules and requirements such as regulations and standards) [23] within the electricity sector. Due to these changes, organisations have to undergo several adaptation processes, which could potentially hugely influence their day-to-day operations, collaborations with other actors and business models [e.g. 12,38]. However, organisations do not have to accept these changes without at least some resistance. They can actively attempt to shape negotiations and new role allocations within these developments [38].

To be able to examine these institutional changes, we draw on new institutionalism. At the centre of this conceptual approach are questions that examine the way organisations respond to institutional pressures [44], the varying institutions that structure an organisational field [21] and the ways in which different organisations influence (and are influenced by) institutional changes [22,45,46]. We make use of the following three concepts: a) organisational field [47], b) pillars of institutions [23] and c) institutional work [24] to analyse how institutionalised rules are challenged through current smart grid developments and how organisational actors attempt to influence efforts to advance smart grid developments.

Organisational fields have been conceptualised as a group of organisations that 'in the aggregate constitute a recognised area of institutional life: key supplier, resource and product consumers, regulatory agencies, and other organisations that produce similar services or products' [47, p. 64]. Rather than defining 'a field around companies with a common product or market', Hoffman [22, p. 352] has stressed that fields should be conceptualised 'around issues that become important to the interests and objectives of a specific collective of organisations' [22, p. 5]. Focussing on issues allows for an investigation of how organisations can 'compete over the definition of issues and the form of institutions that will guide the organisations' behaviour' [22, p. 352]. The concept of 'issue-based-fields' aids the process of revealing greater complexity in field formation and of describing and analysing the dynamics of an issue-based field [22].

The field is conceptualised within a wider organisational environment with several institutions i.e. 'regulative, normative and cultural-cognitive elements that, together with associated activities and resources, provide stability and meaning to social life' [23, p. 56]. The regulative pillar describes the explicit regulative aspects of institutions. Rules, laws, policies, control and sanctions are the key elements and mechanisms of compliance that give meaning to these institutions. The normative pillar makes up the prescriptive, evaluative, and obligatory dimensions of institutions. That pillar is connected to values, social norms, duties, and role expectations i.e. what is considered appropriate behaviour and can be directed at all actors of a particular field [48]. The third pillar in Scott's conceptualisation of institutions is the cultural-cognitive one. This pillar relates to the shared conceptions and frames with which the world is interpreted, or with which meaning is given, such as symbols, discourses and cultural categories.

Considering that 'in highly institutionalised systems, endogenous change seems almost to contradict the meaning of institution' [48, p. 187], the explanations of change within issue-based fields need to be able to conceptualise how institutions constrain actors' behaviours and also how actors can be knowledgeable agents, who are able to influence and change institutions [45]. Thus, the question of institutional change has always dealt with the 'paradox of embedded agency' [49–51]. How is it possible that actors shape institutions whilst at the same time being embedded in institutions that are regulative, normative and cultural-cognitively supported? [46]. In this paper, to overcome the paradox of embedded agency, we draw on the notion of institutionalisation (i.e.

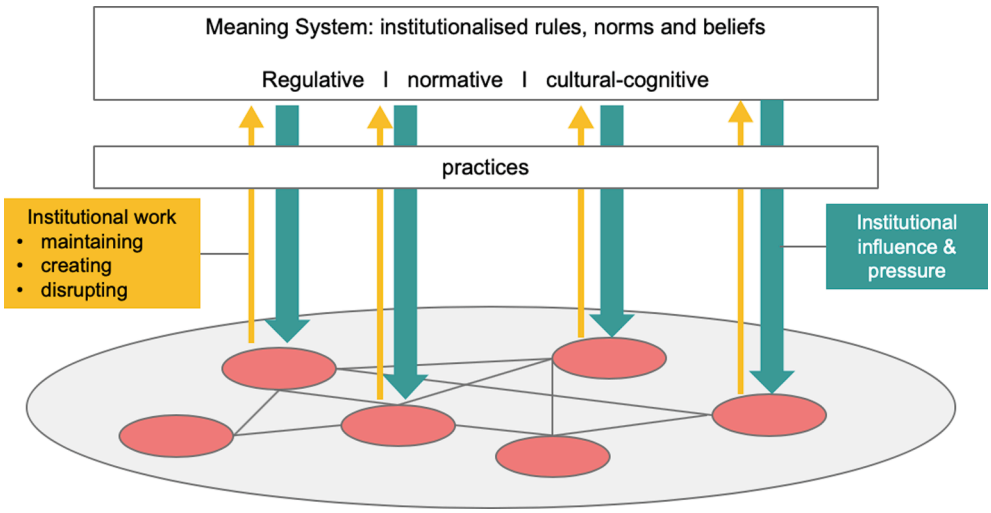

Fig. 1. Institutional Work As Practices In An Organisational Field (Adapted From Möllering [46]).

considering institutional changes as continuous and never finished) and institutional work (i.e. as deliberate activities of individuals and/or organisations that aim to create, maintain and transform institutions). Möllering [46, p. 468] has conceptualised institutional work as practices that are 'the connecting element between single actions and the overarching meaning system of the organisational field (own translation)' (see Fig. 1).

Institutional change does not primarily occur through external shocks, such as economic crises [52]; it also derives from within the field. As Lawrence and Suddaby [24] point out and previous studies have shown [45], it makes sense to explain changes in organisational fields through the emergence of alternative practices that, over time, appear to actors to be more legitimate while the legitimacy of the previously institutionalised practice is eroded as part of the institutionalisation process [45]. By adopting a practice perspective on institutions, Lawrence and Suddaby argue that research can focus on 'the knowledgeable, creative and practical work of individual and collective actors aimed at creating, maintaining and disrupting institutions' [24, p. 12].

In the paper, we draw on the notion of an issue-based field that is an institutionally defined arena formed around contested issues where different actors attempt to shape field level institutions through practices aimed at maintaining, disrupting and creating institutions. This perspective provides a distinct view on institutional change processes that emerge from within issue-based fields and can enrich current discussions about the ongoing social change processes related to developing smart grids. In this paper, we investigate which activities, referred to as acts of institutional work [referring to 53], organisations undertake to influence the institutional order and accelerate or slow down smart grid developments. Moreover, we investigate how organisations in the smart grid field coordinate these activities that is marked by uncertainties and try and shape institutional arrangements in relation to their own interests.

4. Methodology

The fieldwork for this research has been conducted as part of the research project 'Energienetz Berlin Adlershof'. The aim of that project was to set up a multi-energy-microgrid in an industrial and research park in Berlin. The challenge was to create networks made up of different energy carriers that can support the balancing of fluctuating renewable generation [54]. Considering the focus of the paper on forms of institutional work that are linked to actors' ways of working and interacting with each other, we draw on mixed-methods qualitative research: in-depth interviews and a document review.

We conducted 18 in-depth interviews between 2015 and 2018 with a diverse set of actors from organisations linked to the Adlershof project and other German smart grid pilot projects (i.e. two large smart grid implementation funding programmes called E-Energy and SINTEG) (see appendix for detailed information about who was interviewed). The interview sampling process was mainly purposeful sampling followed by snowball sampling [55]. We started with actors from the Adlershof pilot project and then asked the interviewees about other relevant actors within the German smart grid field. We stopped interviewing once no new actor group was suggested by the interviewees and themes within the interviews started to repeat themselves (i.e. saturation point was reached). The sample includes research institutions, transmission system operators (TSO), distribution system operators (DSO), aggregators, ICT/hardware/software-providers, energy suppliers, commercial customers, policy/public administration and a local district energy manager (see Appendix). The face-to-face and telephone interviews lasted 1–2 h. Interviewees were asked about their definition of smart grids, their organisation's response to the German smart grid agenda, relevant actors they engage with (or not), and particular interests and activities they follow to influence any developments. We did not interview private householders because our focus was on organisations and their roles in smart grid developments.

We combined the interviews with a document review to reveal relevant policy activities for smart grid developments in Germany. Documents included statement papers from different organisations regarding the 'law on the digitalisation of the Energiewende' and related press statements. The sample of 41 documents included statements from TSO, DSO, associations representing different sectors (such as ICT/hardware/software providers, retailers, energy providers and municipally owned energy providers), public authorities and non-profit associations.

The evidence gathered was coded and a thematic analysis was conducted, making use of the qualitative analysis software NVivo. The analysis was carried out in two phases. First, we used an inductive approach to identify empirical themes connected to smart grid developments. Several themes emerged from this coding process, e.g. actors' changing roles, activities to prepare for the smart grid agenda and expected benefits associated with smart grid developments. Second, we analysed the interviews according to theoretically informed themes, including the examination of the issue-based field and forms of institutional work related to regulatory, normative and cultural and cognitive changes. This in-depth analysis allowed us to gain insight into the contested issues that are part of institutional change processes connected to smart grid developments in Germany. The documents were analysed for existing and expected contestations with a focus on changing roles and responsibilities when it comes to smart grid

Table 1
Constituencies of The German Smart Grid Field (Italic Entries: Number of Organisations Directly Engaged In The Considered Smart Grid Pilot Projects).

Organisations/group of actors	Most relevant organisations in Germany	Main role(s) in existing German electricity system
Politics/public administrations(e.g. ministries and regulatory bodies)	• Federal Ministry for Economic Affairs and Energy (BMWi) • Federal network Agency (BNetzA) • Federal Office for Information Security (BSI)	• Provide regulations and standards • Initiate and implement legislations • Control and approve grid usage fees • Ensure the 'proper' operation of the electricity network • Ensure IT- and data security (esp. with regard to smart meter technologies)
Transmission system operators (TSO)	• 50 Hertz • Amprion • Tennet • TransnetBW • *All 4 TSO engaged in smart grid pilot projects*	• Plan and maintain the high voltage grid • Guarantee the uninterrupted exchange of electricity • Ensure transmission grid stability despite fluctuating renewable energies • Coordinate transmission grid activities
Distribution system operators (DSO)	• 883 organisations (to some extend municipally owned , Stadtwerke') • *21 DSO engaged in smart grid pilot projects (including 'Stadtwerke')*	• Operate (and sometimes own) energy distribution networks • Ensure that generation and consumption levels are balanced at all times • Coordinate distribution grid activities including sectoral coupling (e.g. mobility, power-to-x, heat pumps)
Energy providers	• 4 large organisations in Germany (E.ON, Vattenfall, RWE, EnBW) and several SME (partly municipally owned) • *41 organisations engaged in smart grid pilot projects*	• Organise the production and distribution of energy • Produce centralised energy (e.g. coal- and gas fired power plants and nuclear power plants) • Produce decentralised energy (e.g. wind power, biogas, photovoltaic plants, and heat-pumps)
Retailers	• 59 organisations[1] • *5 Retailer engaged in smart grid pilot projects (some of them are subsumed under energy providers)*	• Trade through buying and selling electricity on the market, from power stations or other energy producers, and pay network fees for using distribution networks
Aggregators	• 12 active aggregators operating in Germany, • *2 Aggregator engaged in smart grid pilot projects*	• Trade and supply energy without managing their own balancing groups • Pool and market generation plants, flexible consumer and storage systems
Industrial & commercial customers	• *10 organisations from several industries engaged in smart grid pilot projects*	• Consume electricity i.e. 73.1% of overall electricity demand in Germany (45.7% industry, 27.4% commercial) • Make use of flexible energy demand through demand side management
Private customers/households	• Private households & neighbourhoods • *one housing cooperative engaged in smart grid pilot projects*	• Consume electricity i.e. 24.6% of overall electricity demand in Germany[2] • Energy prosumers (i.e. producing and consuming electricity)
Research institutions	• More than 1000 publicly finance ones in Germany • *61 research organisations engaged in smart grid pilot projects*	• Conduct research mainly within pilot projects on technological, regulative, social and governance developments
ICT/hardware/software providers	• *64 organisations engaged in smart grid pilot projects*	• Provide ICT, hardware and software-solutions (e.g. smart meter, smart meter gateway, communication interfaces, sensors, actors) • Develop products and services (e.g. platforms, big data analytics, IoT, IT-security and cloud solutions)
Associations	• More than 60 associations within the energy sector • *4 organisations engaged in smart grid pilot projects*	• Represent the interests of their members from various sectors • Engage in policy and market framework developments with regard to smart grids (i.e. smart meter rollout, electricity market design, standardization processes)
Other	• Consultant agencies • Regional economic development agencies • *31 organisations engaged in smart grid pilot projects*	• Conduct consultancy & research • Provide funding • Develop regional networks • Encourage business developments

[1]A current statistic counts 906 electricity network operators, but it remains unclear whether transmission network operators are included: https://de.statista.com/statistik/daten/studie/173884/umfrage/zahl-der-unternehmen-in-den-einzelnen-marktbereichen-des-energiemarktes/.
[2]Transport accounts for the remaining 2.3% of electricity consumption: https://de.statista.com/statistik/daten/studie/236757/umfrage/stromverbrauch-nach-sektoren-in-deutschland/.

developments. We did not focus our analysis on every single social, technological or regulative issue (such as data protection regarding private households) but turned our attention to contestations between organisations including their interactions and relations when implementing smart grids.

5. Findings

To present our findings, we first provide an overview of the relevant actors in the issue-based field. Then, we describe key contested issues and negotiations between different actors that transpire when examining the institutional work undertaken to create, maintain or disrupt the institutions within smart grid developments.

5.1. Smart Grid Actors Within The Issue Based Smart Grid Field (SGF)

The smart grid field is composed of all organisations that 'in the aggregate constitute a recognised area of institutional life' [21, p. 148]. This section provides an insight into the key constituencies of the German smart grid field, i.e. relevant organisations interacting with each other. The German smart grid field is made up of organisations directly engaged in smart grid pilot projects (most relevant are the projects within the E-Energy and SINTEG funding programmes) and organisations that are more generally relevant for smart grid developments in terms of policy and market frameworks and standardisation processes, such as ministries, regulatory bodies and associations (see Table 1). The smart grid field is composed of more established energy actors (e.g. energy providers, public authorities, DSOs and TSOs) and new entrance actors (e.g. ICT/hardware and software providers, aggregators).

Within the issue-based smart grid field, we have identified three core issues and contestations: *1) Who should get access and manage the data derived from smart meters to create smart grids? 2) Who should balance and decide on the flexibility of the distribution network? and 3) Who should be involved in developing demand side innovations for energy customers?* Several other issues also emerged through the data collection and analysis (e.g. security standards of smart grids). In this paper, we focus on the three issues because interviewees mentioned them most

frequently and they draw particular attention to how institutionalised roles, rules and belief systems are being negotiated within smart grid developments. The following three sub-sections illustrate how actors attempt to influence and/or steer changes.

5.2. Who should get access and manage the data derived from smart meters to create smart grids?

In Germany, the electricity grid is managed by four big TSOs and around 900 DSOs (in 2018, there were 883 DSOs[2]), which are responsible for managing the grid. During the development of the regulatory instruments for the smart meter rollout, discussions emerged about the costs and profits connected to the rollout. Beyond issues of general importance, such as data protection and privacy that have also been discussed in other countries [56], the question of access to data was part of emerging contestations amongst organisations between 2015 and 2018 in Germany. One of the core issues was to decide which organisations, such as DSOs, TSOs, energy provider and/or aggregator should gain access to the data collected by the smart meter. In Germany, the discussions especially occurred between DSOs and TSOs. Although DSOs were responsible for installing the smart meters and managing the repayment from consumers, the TSOs wanted to claim access to the data collected by smart meters and promote their new role as 'data platform operators' within smart grids. These differing expectations about who would get access and manage the data created a fundamental conflict between TSOs and DSOs that could be witnessed at events organised by standardisation bodies (e.g. DIN, German Institute for Standardisation).

> 'During events organised by the standardisation bodies that regulate collaboration between TSOs and DSOs, sparks are currently flying. The topic is filled with politics, who can get access to what type of data.' (Interview#12)

The TSOs argued that it makes sense to shift demand-side management responsibilities connected with the smart meter rollout to them instead of leaving the responsibility with the DSOs. Their main argument was that it is not efficient to build data management tools for each of the nine hundred DSOs but rather to go for the notion of 'concentration and centralisation' through the TSOs.

> 'This was the big discussion […] if this new tool needs to be created then it makes sense […] to build it once or four times rather than nine hundred times.' (Interview #3, TSO)

The DSOs tried to defend their responsibilities by referring to their existing expertise and experience in interacting and managing their consumer base, as outlined by one of the DSO interviewees, speaking about the future prospect of TSOs taking on board some of their current roles:

> 'I feel it is foolhardy for them to get access to our distribution networks and even potentially control flexible consumers. They will not be able to do this. There is a lot of politics involved in these activities.'(Interview #14, DSO)
> 'Regulations should not lead to existing contractual relationships being unnecessarily blown up so that they become expensive and impractical in their application. This will not increase the acceptance of consumers and will enhance bureaucracy for all parties.' ([57][3], Association of publicly owned companies)

The DSOs have felt disadvantaged through the proposal of the law, as outlined by the Association of Municipal Companies (VKU) press release statement:

> 'The VKU (…) views this proposal as a fundamental interference into established roles that disadvantages DSOs. The grid balancing responsibilities that currently lie with the DSOs would be transferred to the TSOs.' ([57], Association of publicly owned companies)

The shift of responsibilities from DSOs to TSOs was also criticised by the Association of Software and Service Providers:

> 'The shift of competences from the DSOs to the TSO will affect the DSOs in the future […] In a more decentralised energy world, responsibility should generally remain decentralised, which is why we are very critical of the shift of responsibility' ([57], Association of publicly owned companies)

Within the process, the DSOs put forward the argument that more actors need access to the data for grid management purposes:

> 'Only if the distribution network operator has unrestricted, prompt and as direct access as possible to the relevant data will [the DSO] be able to control the networks intelligently in future and thus make a decisive contribution to the success of this transformation process towards more decentralised structures." ([57], Association of publicly owned companies)

At that time, the four TSOs were partly privileged because they got funding from the German government to develop data handling systems that allow them to get access to aggregated data from smart meters for grid management activities, as suggested by one of the TSOs interviewees:

> 'They argued that they do not forbid DSOs to build their own system, we just pay for it four times […] We do not want to act like Google and make use of people's data. We just consider it to be a regulatory role. Any third party can make use of the data if they gain the permission of the customer.' (Interview #3, TSO)

These issues and negotiations illustrate the acts of institutional work that are conducted within these change processes by the different smart grid organisations. TSOs have mainly tried to *create* institutional arrangements to establish their new role within a smart grid (i.e. owner and manager of data created by smart meters). They have made a case for the centralisation of data management and concentration of financial resources to be able to reconfigure the existing institutional settings in the energy sector (i.e. gaining access to the distribution network and its customer base). The 'centralisation' argument has put the DSOs in the position of defending the incumbent order (i.e. their existing roles and responsibilities in managing the distribution networks). The final decision within this process, which was achieved in 2019 was the concept of a star-shaped communication from smart meter gateways, i.e. data is processed within smart meter gateway and only the actors who get permission from the energy customer are able to access that customer's data.

5.3. Who should balance and decide on the flexibility of the distribution network?

Since renewable energy is often produced within decentralised networks, the distribution grid is strongly affected by the changes that go alongside smart grid developments. There is a growing need to develop flexible networks within the distribution grid. At the moment, the role of the DSOs is to transmit energy and, as a result, keep the grid stable. In the future, they will have to introduce new flexibility methods (e.g. demand-side response), creating interconnections between 'more intelligent' energy producers and consumers. Discussions surrounding the future role of the DSOs are often at the heart of smart grid developments because their role must fundamentally change, albeit within the

[2] Bundeskartellamt (n.d.). Number of electricity network operators in Germany in the years 2006 to 2018. Statista. Available at https://de.statista.com/statistik/daten/studie/152937/umfrage/anzahl-der-stromnetzbetreiber-in-deutschland-seit-2006/ (Access: 20.01.2021).

[3] DSO & Public Utility Association

confines of existing regulations, i.e. since the unbundling directive, implemented at the beginning of the 2000s, DSOs have to operate independently of the local utility. Moreover, it remains unclear if the DSOs (especially the smaller ones) are willing and able to fulfil these expected roles. For this actor group, developing the capacity and resources to create smart grids still seems to be a long way away, as one interviewee has argued:

> 'For part of our field experiment in Lower Bavaria, there is a medium-voltage grid where nothing is digital.' (Interview #12, Research Institution)

Current measuring instruments are relatively rudimentary when it comes to more 'intelligent' ways of balancing the grid. Numerous operations rely on reading the measuring equipment manually and are far from being digitalised. Furthermore, our research has shown that this actor group is comparatively heterogeneous, not only because of the size of the distribution network and energy mix in the network or the ownership structures (i.e. municipally or privately owned) but also with regard to the actors' aims and strategies. Actors' interests, roles and aspirations towards a smart grid are extremely diverse (e.g. large DSOs are pushing smart grid developments forward and smaller ones are much more conservative). Shared visions are hard to develop across this group. Not all DSOs try to prevent institutional changes towards smart grid developments. Some of the DSOs are innovative and try to engage in pilot projects, as one interviewee has put it:

> 'But on the whole, in our pilot project, the DSOs definitely play a driving role and are somehow visionary regarding these developments' (Interview # 12, Research Institution)

Current developments might be more challenging for smaller DSOs because of a lack of financial or personal resources and because of the uncertainty regarding regulative developments:

> 'With distribution system operators, it is often more difficult because the distribution system operators are also in a situation of uncertainty' (Interview #1, Aggregator)

Another challenge is the coordination and management of grid bottlenecks i.e. grid congestion can occur when grid overload makes it impossible for electricity to reach consumers. If the TSOs want to be able to gain control to balance the grid and keep it stable (in case of a huge amount of renewable energy), they might also cause balancing problems for the distribution grid. At the moment, there is no coordination mechanism that DSOs and TSOs draw upon to reach an agreement whenever these situations occur. The market mechanisms to enhance grid flexibility are in tension with grid bottlenecks at the distribution level:

> 'One great challenge that we are currently dealing with and more frequently have to engage with is that restrictions derived from the DSOs i.e. bottlenecks within the DSO grid limit possible market mechanisms.' (Interview #2, Aggregator)

Discussions have arisen about how this problem can be tackled, and whether DSOs are able and willing to solve it remains unclear. Having to balance the power flow within the grid and market-related activities (such as demand side management and related business models) have posed great challenges for the DSOs, in particular, in maintaining grid stability. Ultimately, this stability remains a challenge for the implementation of smart grids and is closely associated with discussions around expected actors' roles in future smart grids.

> 'The biggest challenge for developing a smart grid is (…) to manage the complexity of bringing together the different actors involved and varying incentives for actors so that everything [the whole grid] can function in the end.' (Interview #7, Policy/Public Administration)

Our empirical findings also illustrate that the DSOs are not one coherent group and that they have been engaged in two different acts of institutional work. Some DSOs tried to *maintain* existing ways of working in the energy sector, in particular, trying to emphasise their existing expertise and capabilities in stabilising the distribution networks. Other DSOs (which can also be energy providers since they sometimes belong to the same organisation, i.e. municipally owned "Stadtwerke") engaged in *creating* novel institutional arrangements by trying to find new ways of managing the growing grid flexibility. Those DSOs do not want to lose out on potential profits of future smart grid developments and thus engage in pilot projects to support capacity building. Since the organisations involved are facing uncertainty regarding future developments of the institutional setting, they engage in diverging acts of institutional work and act differently to cope with the uncertainties.

5.4. Who should be involved in developing demand side innovations for energy customers?

Smart grid development has opened up questions about how to promote greater flexibility at the demand side and establish novel business models that create added value for customers. Emerging actors have started to enter the field, such as aggregators and ICT-companies, who have gained influence through creating a diverse set of novel technologies, business models and value chains [14] e.g. the creation of virtual power plants (VPP). These organisations frequently challenge the incumbent order by establishing their new roles and practices within the energy system and engaging in institutional work aimed at 'disrupting' existing institutional arrangements. Thus, they have questioned the existing regulative institutions and tried to establish new business models and roles within the energy market.

> 'Our interest is to change the rules of the electricity market. In the past, these rules were understandably made in the interest of the producer and a centralised grid. We still are long way off from, let's say, the famous 'level playing field'. We ask ourselves how we can establish new business models and roles in the energy market.' (Interview #2, Aggregator)

Another interviewee described how the organisation tried to influence the policy process concerned with developing smart grids and explained that it wants to establish a novel role for aggregators in the German energy market. It wants to get access to demand-side management markets, which have, so far, been partly restricted to them:

> 'To be able to push these topics [access of aggregators to demand side management market], I am active in associations that attempt to directly talk to ministers, regulatory bodies and commissions.' (Interview # 1, Aggregator)

Since many organisations in the field face high levels of uncertainty regarding future business models, market constellations and opportunities, there are opposing interests between emerging actors, such as aggregators, and incumbent organisations, such as DSOs and energy providers. For the aggregator, it is important to access the demand-side management market by offering business models and gaining access to energy customers. But this interest collides with existing activities of energy providers. Energy providers have tried to prevent new legislations aimed at opening up the energy market for more actors (such as aggregators) and have thus engaged in institutional work to *maintain* existing institutional arrangements. Aggregators have tried to influence legislation to establish their role and engaged in institutional work aimed at *creating* new institutions.

The institutional work conducted by the actors involved addressed not only the regulative dimensions of current institutions but also normative ones. To attempt to change the normative institutional pillar, they developed industry sector guidelines, which defined standardisation processes about how aggregators and energy providers should interact with each other. The processes associated with developing these

guidelines were highly contested because of diverging actor interests:

> 'Well, there are conflicting interests, that is clear. The starting position is such that nowadays, the aggregator needs the approval of the supplier and this should be changed now. Over the past eight, nine months, there have been intensive discussions in the industry sector about this topic… industry sector guidelines have been developed. How can the aggregators be established in the balancing power market so that they are no longer as dependent on energy suppliers as they have been in the past and now but rather are able to act independently?' (Interview #2, Aggregator)

Another important actor group that has reconfigured the field is that of start-ups, including ICT-companies, providing business models for flexibility management (e.g. new energy retailers and electricity sharing platforms). These organisations frequently introduce novel ways of finding solutions for flexibility issues and opportunities (e.g. flexible tariffs and local electricity sharing networks). Moreover, actors within these organisations have competences (such as programming and data processing skills) that influence field developments (e.g. by creating new data-based business models).

> 'Company (..) is an IT-business that also does a bit of work on energy. For them, these products are not a problem. Let's just roughly try it. And this is a lot easier for smaller companies than for bigger ones. Especially because the larger companies have been spoiled. And now this is changing. But the people wrapped in cotton wool still are around.' (Interview #16, ICT/Hardware/Software Provider)

Our findings indicate that the actors involved are engaging in different acts of institutional work within the issue-based smart grid field. Whereas some emerging actors (e.g. aggregators) aim to *change* regulative institutions (e.g. energy market rules), other actors (e.g. mainly those entering the field from the start-up and IT-related sectors) *create* institutions through developing new business models (e.g. flexible tariffs) and organisational forms (e.g. energy-exchanging platforms). They establish new practices related to innovative demand-side management and flexibility opportunities within smart grids. Since established actors (e.g. incumbent energy providers) are engaging in institutional work to *maintain* the institutional order (e.g. restraining access to balancing power markets), we want to show the diverging forms of institutional work within the smart grid field, which we discuss in the next section.

6. Discussion

The findings illustrate that, from an institutional perspective, the smart grid field in Germany is still in the process of being re-institutionalised [45] and diverse organisations are acting under conditions of field-level uncertainty [58]. As previous studies have shown, institutional change processes are more likely to occur in times 'when no-one knows what will work and the field is 'opportunity hazy'' [59]. This fuzziness is particularly true for the smart grid field, where diverging visions exist of what constitutes a smart grid [5] and different structural, functional and cultural features are possible [60]. These properties have opened up spaces for contested issues and negotiations over existing and possible future institutional arrangements. Since the smart grid field is populated by 'diverse organisations, many of whom are invested in, committed to, and advantaged by existing structural arrangements' [58, p. 962], diverse actors in the field undertake different efforts to 'create', 'maintain' or 'disrupt' the existing institutional setting [61]. Drawing on research that has investigated institutional work [61] and, in particular, on the work related to the semiconductor industry [59], we have identified five different forms or 'acts' of institutional work [53] conducted by actors in the German smart grid field (see Table 2). These acts are key to understanding the institutional change processes.

Some of the field actors have been engaged in acts of *pooling* i.e. trying to concentrate financial support and channel resources in favour of their own interests. Our findings have shown that negotiations about the future role of DSOs were substantially influenced by the distribution of financial resources for implementing data management systems to handle energy data (linked to the smart meter rollout). In those negotiations, the four TSOs in Germany argued for concentrating the resources connected to creating institutional arrangements needed for the rollout, which greatly strengthened their position in the field to manage and control the data. Such *pooling* acts are a tangible illustration of how organisations, in this case the larger ones in particular, reconfigure the field in favour of their own interests due to a lack of a coherent vision [5] of what the smart grid should be.

Another form of institutional work that we found is what we refer to as *playing up,* i.e. established actors try to maintain the institutional order when it comes to introducing data management platforms. They use their inherent legitimacy within the existing energy system to argue that only they understand the complexity of the distribution grid operations. As a form of institutional work, some actors have also been

Table 2
Forms of institutional work within the smart grid field.

Forms of institutional work	Definition	Institutional work addressed	Occurrence within the smart grid field	Illustrative evidence derived from the data
Pooling	Actors channel resources and concentrate financial support to leverage the contested space.	*creating*	• Contestation between DSO & TSO • Conflicting practices • Slowing smart grid developments	*'They argued that they do not forbid DSOs to build their own system, we just pay for it four times.' (Interview #3)*
Playing up	Established actors use their inherent competences and legitimacy to perpetuate the social order.	*maintaining*	• DSO are defending their established role • Playing up their distinct competences regarding grid management	*'This is a fundamental interference into the established roles' (…) so (…) in our opinion, the transmission system operators (underestimate) the complexity in a distribution network'* [57]
Standardising	Actors introduce nascent rules and standards to reconfigure the field in favour of their particular interests.	*creating*	• Aggregators and energy providers develop guidelines and standards for the industry sector • Define new roles within future smart grids	*'We worked together to develop a guideline and defined sector standards' (Interview #2)*
Advocating	Actors attempt to influence legislation either to maintain or create institutions.	*creating/ maintaining*	• Energy providers influence policy developments to defend their traditional business models • Aggregators aim to influence policy processes to stabilise their new roles and business models	*'To be able to push these topics, I am active in associations that attempt to directly talk to ministers, regulatory bodies and commissions.'(Interview #2)*
Gap Filling (similar to bootstrapping)	Introducing new competences (from other fields such as IT) and showing unfamiliar ways/defining new practices.	*disrupting*	• IT companies enter the smart grid field with new competences and ways of doing things (such as data-driven business-models)	*'New players see it more as an opportunity to fill regulatory gaps and develop new business models' (Interview #16)*

conducting *standardising* [62], which can be described as the introduction of 'nascent rules and standards' so that some actions become normatively sanctioned within the field [24] and which is also used to reduce uncertainty [63, p. 424]. To overcome the contestations, the energy providers and aggregators developed sector guidelines, which function as a normative framework and provide orientation and a basis for coordinating the activities. This form of institutional work is similar to what has been identified as 'creating normative networks' [24]. By engaging in this form of institutional work, the actors involved are mainly seeking to coordinate actions between the organisations within the field or to create an institutional setting that provides some kind of stability and direction for possible future business opportunities.

Acts of '*advocating*', which also have been identified by previous studies [64,65] can be found as well. Our findings reveal that this form of institutional work is not only attached to creating institutions but also to disrupting existing institutional settings. In the German smart grid field actors (such as aggregators) try to influence policy processes in order to create a regulative order in which they can establish new roles for themselves within the energy sector. Other actors (such as the Federation of Distribution-Net-Operators' (German: VKU) conduct advocacy work against such fundamental regulation in order to maintain their roles and responsibilities. Our findings have shown that some actors have been very opportunistic in trying to identify gaps in competences arising from smart grid developments and then attempting to fill them, in being involved in *gap filling*. This form of institutional work is similar to what Möllering & Müller-Seitz [59] have called 'bootstrapping' but, in the smart grid field, the focus is slightly different to that in the semiconductor industry: Actors engage in self-starting action without knowing what the future will hold and are filling gaps with new business models (e.g. selling energy with flexible tariffs or via peer-to-peer platforms) and unfamiliar ways of doing things. These actors are crucial for the changes within the field because new actors with novel ideas, competences and even distinct meaning systems are entering the energy sector. As catalysts for change [14], these actors are populating the field with their own visions and narratives [66], triggering the reconfiguration of the established institutional setting.

These five forms of institutional work identified within the smart grid field in Germany are neither exclusive nor overarching. But they do provide important evidence of the heterogeneity of actors' roles and the inter-organisational dynamics [19] within the smart grid field. No single organisation has been able to claim to have an overarching vision [5] on what is really needed to develop a smart grid and create a sustainable energy system in Germany. Many organisations involved in smart grid developments face high uncertainties [58]. As our findings reveal, the organisations are engaging in different forms of institutional work regarding smart grid developments and thus reflexively engage with the institutions that surround them [63].

7. Conclusions

This paper shows how existing roles, rules, norms, and beliefs within and between organisations are challenged (or not) through smart grid developments, and how actors try to collectively shape institutional arrangements within energy systems' transformations. In the German smart grid field, we identified three core contestations amongst the organisations involved, those related to the *management of data*, those related to *responsibilities for managing the growing flexibilities in distribution grids* and those related to the *division of roles to develop demand-side innovations*. Our empirical findings indicate that organisations' activities linked to these contestations are grounded in five different forms of institutional work, namely *pooling, playing up, standardising, advocating* and *gap filling*.

We advance the social science research on smart grids in three different ways. First, we have shown that analysing institutional work in issue-based fields provides a useful conceptual framework to understand how organisations try to shape current smart grid developments and legitimise some rules and norms over others [67]. This shaping and legitimising cannot be purely explained by a challenger-incumbent dualism [68,69]. The heterogeneity of organisations' aims, interests and belief systems, as highlighted by our examination of institutional work, are key to understanding why smart grid developments lag behind initial expectations. The rules (e.g. who gets access to the market) and roles (e.g. who should handle the data and/or who should manage grid flexibility) in future smart grids are not clearly defined and thus highly contested among the organisations. The struggle is much more about an individual organisation's interests than about a wider governmental and/or public debate [66] as to what constitutes a smart grid, the main purpose it should serve and how it could be organised. Organisations that currently make up the German issue-based smart grid field provide some evidence of 'who is actually benefiting from the 'smart' on the grids' [66, p. 24] and that private-industry actors are one of these beneficiaries [19].

Our second contribution relates to the idea that the development of digital infrastructure 'adds both complexity and uncertainty to the operation of the electricity system of the future' [70, p. 86]. Our findings have shown that the organisations involved act in a field with relatively high uncertainty [58]. These uncertainties are created, in part, from the lack of clear regulative developments that would allow organisations, for example, to create new rules to coordinate and manage grid bottlenecks. To be able to overcome these uncertainties, organisations have engaged in diverse forms of institutional work to define rules, roles and responsibilities for the electricity system of the future. We argue that institutionalisation processes in the smart grid field can be regarded as overcoming the current lack of coordination between the involved organisations [59]. To go beyond the pilot stage in smart grid developments, there seem to be a profound need for public policy [35] and a shared and institutionalised vision as to how a smart grid should look so that it can contribute to a low-carbon energy system.

Our third contribution relates to the idea that smart grids are incremental and context-related endeavours [35] as well as being socially constructed and institutionally embedded [36]. Our analysis has shown that changes linked to smart grid developments are frequently linked to changes in rules (e.g. opening up the energy market for new actors such as aggregators) or norms (developing industry standards and guidelines for smart grids). Established organisations such as DSOs and energy providers engage in institutional work to maintain the existing institutional arrangements and, at the same time, establish favourable roles for themselves in ongoing changes. Our findings indicate that the developments related to smart grids have much to do with changing the taken-for-granted meaning systems within the energy system (e.g. by whom and how should it be organised and run). New entrance organisations attempt to change the accepted meaning systems (through, for instance, setting up energy exchange platforms), but the underlying cultural-cognitive aspects of the institutional order in the current energy system are much harder to reconfigure than the regulative and normative ones [71]. Digital technologies allow organisations to be connected with each other in novel ways (e.g. DSOs and TSOs) but developing such connections does not necessarily go along with changes in the organisations' accepted belief systems (e.g. about their role in the energy system). Changing accepted belief systems is key if new roles and responsibilities are to be defined and divided between organisations. No organisation wants to give up its dominance and control over managing certain aspects of the energy system, but preferably wants to gain new ones through smart grid developments.

Changes to cultural-cognitive institutions such as meaning systems are key within institutionalisation processes [71]. Meaning systems consist of elements that determine organisations' perceptions of reality and sense making i.e. internal interpretative processes that are shaped by external cultural frameworks [48, p. 57]. Policymakers have often attempted to shape smart grid developments through bringing in regulations (e.g. the German law on the digitisation of the "Energiewende") not acknowledging the need for changing the meaning system or

patterns of thought of the organisations within the German energy system. A recent study in Germany argued 'for such a fundamental change to succeed, established patterns of thought must be identified and overcome [70, p. 6]. If the organisations do not collaborate in reorganising the energy system, preferring to engage in institutional work to maintain existing institutional arrangements, and if policy-makers do not think beyond regulative changes, our findings have shown that a situation emerges where those organisations seem to shape smart grid developments in accordance with their own interests and accepted ways of working. It comes as no surprise that there currently does not appear to exist shared understandings of how a low-carbon energy system based on digital technologies could be organised and implemented.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This research received funding from the project "Energienetz Berlin Adlershof" (no. 03ET1038G) financed by the German Federal Ministry for Economic Affairs and Energy (BMWi). The authors are appreciative to the European Union's Horizon 2020 research and innovation programme under grant agreement No 837498, SONNET and the German Federal Ministry of Education and Research (BMBF) under Grant agreement No 01UU1607B, 'Digitalization and Sustainability' which have supported elements of the work reported here.

Appendix

Table 3

Table 3
Interviews by type of organisation.

Number	Type of Organisation[1]
Interview #1	*Aggregator/SINTEG Pilot Project*
Interview #2	*Aggregator/SINTEG Pilot Project*
Interview #3	*Transmission System Operator (TSO)/SINTEG Pilot Project*
Interview #4	*Energy Provider/E-Energy Pilot Project*
Interview #5	*Industrial Consumer/Adlershof Project*
Interview #6	*Local District Energy Manager/Adlershof Project*
Interview #7	*Policy/Public Administration*
Interview #8	*Research Institution/Adlershof Pilot Project*
Interview #9	*Research Institution Adlershof Pilot Project*
Interview #10	*Research Institution/Adlershof Pilot Project*
Interview #11	*Research Institution/SINTEG Pilot Project*
Interview #12	*Research Institution/SINTEG Pilot Project*
Interview #13	*Research Institution/E-Energy Pilot Project*
Interview #14	*Research Institution/E-Energy Pilot Project*
Interview #15	*ICT/Hardware/Software-Provider/E-Energy Project*
Interview #16	*ICT/Hardware/Software-Provider/SINTEG Project*
Interview #17	*Distribution System Operator (DSO)*
Interview #18	*Distribution System Operator (DSO)*

[1]Due to anonymisation we can not provide information on which interviewee is from which pilot project because this would allow to identify the respective organization.

Table 4

Table 4
Pilot Projects Included In The Sample For Identifying The Smart Grid Field.

	Project name
E-Energy	Energienetz Berlin Adlershof
	E-DE-MA
	MeRegio
	RegModHarz
	Web2Energy
	eTelligence
	Smart Watts
SINTEG	C/Sells
	WINDNODE
	NEW 4.0
	DESIGNNETZ
	enera

References

[1] S. Blumsack, A. Fernandez, Ready or not, here comes the smart grid!, Energy 37 (1) (2012) 61–68, https://doi.org/10.1016/j.energy.2011.07.054.
[2] S. Muench, S. Thuss, E. Guenther, What hampers energy system transformations? The case of smart grids, Energy Policy 73 (2014) 80–92, https://doi.org/10.1016/j.enpol.2014.05.051.
[3] C. Clastres, Smart grids: Another step towards competition, energy security and climate change objectives, Energy Policy 39 (9) (2011) 5399–5408, https://doi.org/10.1016/j.enpol.2011.05.024.
[4] G.P.J. Verbong, S. Beemsterboer, F. Sengers, Smart grids or smart users? Involving users in developing a low carbon electricity economy, Energy Policy 52 (2013) 117–125, https://doi.org/10.1016/j.enpol.2012.05.003.
[5] A. Tricoire, Uncertainty, vision, and the vitality of the emerging smart grid, Energy Research & Social Science 9 (2015) 21–34, https://doi.org/10.1016/j.erss.2015.08.028.
[6] W. Konrad, D. Scheer, Gesellschaftliche Implikationen des Smart Grid im Expertendiskurs - Ergebnisse des Gruppendelphi-Workshops am 30.9.2014 in Stuttgart, InnoSmart-Arbeitsbericht 04, 2015.
[7] T.M. Skjølsvold, M. Ryghaug, T. Berker, A traveler's guide to smart grids and the social sciences, Energy Research & Social Science 9 (2015) 1–8, https://doi.org/10.1016/j.erss.2015.08.017.
[8] R. Smale, B. van Vliet, G. Spaargaren, When social practices meet smart grids: Flexibility, grid management, and domestic consumption in The Netherlands, Energy Research & Social Science 34 (2017) 132–140, https://doi.org/10.1016/j.erss.2017.06.037.
[9] A. Lösch, C. Schneider, Transforming power/knowledge apparatuses: the smart grid in the German energy transition, Innovation: The European Journal of Social Science Research 29 (3) (2016) 262–284, https://doi.org/10.1080/13511610.2016.1154783.
[10] F. Reetz, C. Göhlich, Prinzipien für die Energiepolitik der Zukunft (2020) 34.
[11] F.W. Geels, From sectoral systems of innovation to socio-technical systems, Research Policy 33 (6-7) (2004) 897–920, https://doi.org/10.1016/j.respol.2004.01.015.
[12] L. Gailing, T. Moss (Eds.), Conceptualizing Germany's Energy Transition, Palgrave Macmillan UK, London, 2016.
[13] S. Becker, R. Beveridge, A. Röhring, Energy Transitions and Institutional Change: Between Structure and Agency, in: L. Gailing, T. Moss (Eds.), Conceptualizing Ger. Energy Transit. Inst. Mater. Power Space, Palgrave Macmillan UK, London, 2016: pp. 21–41. https://doi.org/10.1057/978-1-137-50593-4_3.
[14] S. Erlinghagen, J. Markard, Smart grids and the transformation of the electricity sector: ICT firms as potential catalysts for sectoral change, Energy Policy 51 (2012) 895–906, https://doi.org/10.1016/j.enpol.2012.09.045.
[15] L. Fuenfschilling, B. Truffer, The structuration of socio-technical regimes—Conceptual foundations from institutional theory, Research Policy 43 (4) (2014) 772–791, https://doi.org/10.1016/j.respol.2013.10.010.
[16] P. Andrews-Speed, Applying institutional theory to the low-carbon energy transition, Energy Research & Social Science 13 (2016) 216–225, https://doi.org/10.1016/j.erss.2015.12.011.
[17] M. Nilsson, L.J. Nilsson, R. Hildingsson, J. Stripple, P.O. Eikeland, The missing link: Bringing institutions and politics into energy future studies, Futures 43 (10) (2011) 1117–1128, https://doi.org/10.1016/j.futures.2011.07.010.

[18] M. Jehling, M. Hitzeroth, M. Brueckner, Applying institutional theory to the analysis of energy transitions: From local agency to multi-scale configurations in Australia and Germany, Energy Research & Social Science 53 (2019) 110–120, https://doi.org/10.1016/j.erss.2019.01.018.
[19] M.E. Kallman, S. Frickel, Nested logics and smart meter adoption: Institutional processes and organizational change in the diffusion of smart meters in the United States, Energy Research & Social Science 57 (2019) 101249, https://doi.org/10.1016/j.erss.2019.101249.
[20] E. Schmid, B. Knopf, A. Pechan, Putting an energy system transformation into practice: The case of the German Energiewende, Energy Research & Social Science 11 (2016) 263–275, https://doi.org/10.1016/j.erss.2015.11.002.
[21] P.J. DiMaggio, W.W. Powell, The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields, American Sociological Review 48 (2) (1983) 147, https://doi.org/10.2307/2095101.
[22] A.J. Hoffman, Institutional Evolution and Change: Environmentalism and the U.S. Chemical Industry, AMJ 42 (4) (1999) 351–371, https://doi.org/10.5465/257008.
[23] W.R. Scott, Institutions and organizations: Ideas and interests, Sage, Thousand Oaks, California, 2008.
[24] T.B. Lawrence, R. Suddaby, Institutions and Institutional Work, in: S.R. Clegg, C. Hardy, T.B. Lawrence, W.R. Nord (Eds.), SAGE Handb. Organ. Stud., SAGE Publications Ltd, London, 2006: pp. 215–254. https://doi.org/10.4135/9781848608030.n7.
[25] R. Mayntz, The Study of Organizations, Current Sociology 13 (3) (1965) 95–119, https://doi.org/10.1177/001139216501300301.
[26] M. Goulden, B. Bedwell, S. Rennick-Egglestone, T. Rodden, A. Spence, Smart grids, smart users? The role of the user in demand side management, Energy Research & Social Science 2 (2014) 21–29, https://doi.org/10.1016/j.erss.2014.04.008.
[27] S. Nyborg, Pilot users and their families - inventing flexible practices in the smart grid, Sci. Technol. Stud. 28 (2015) 54–80.
[29] F. Gangale, J. Vasiljevska, C.F. Covrig, A. Mengolini, G. Fulli, Smart grid projects outlook 2017, Jt. Res. Cent. Eur. Comm, Petten Neth, 2017.
[30] Bundesnetzagentur, "Smart Grid" und "Smart Market" Eckpunktepapier der Bundesnetzagentur zu den Aspekten des sich verändernden Energieversorgungssystems, German Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway, 2011.
[31] BDEW, BDEW Roadmap. Realistic Steps for the Implementation of Smart Grids in Germany., German Federal Association of the Energy and Water Industry (BDEW), 2013.
[32] Y. Wang, Q. Chen, T. Hong, C. Kang, Review of Smart Meter Data Analytics: Applications, Methodologies, and Challenges, IEEE Trans. Smart Grid 10 (3) (2019) 3125–3148, https://doi.org/10.1109/TSG.2018.2818167.
[33] Ernst & Young GmbH, Barometer Digitalisierung der Energiewende. Ein neues Denken und Handeln für die Digitalisierung der Energiewende, Berichtsjahr (2018, 2019.).
[35] A. Kumar, Beyond technical smartness: Rethinking the development and implementation of sociotechnical smart grids in India, Energy Research & Social Science 49 (2019) 158–168, https://doi.org/10.1016/j.erss.2018.10.026.
[36] M. Wolsink, The research agenda on social acceptance of distributed generation in smart grids: Renewable as common pool resources, Renewable and Sustainable Energy Reviews 16 (1) (2012) 822–835, https://doi.org/10.1016/j.rser.2011.09.006.
[37] C. Zhang, J. Wu, C. Long, M. Cheng, Review of Existing Peer-to-Peer Energy Trading Projects, Energy Procedia 105 (2017) 2563–2568, https://doi.org/10.1016/j.egypro.2017.03.737.
[38] J.C. Stephens, E.J. Wilson, T.R. Peterson, Smart grid (R) evolution, Cambridge University Press, New York, 2015.
[39] D.-yin. Mah, Y.-Y. Wu, J.-man. Ip, P.R. Hills, The role of the state in sustainable energy transitions: A case study of large smart grid demonstration projects in Japan, Energy Policy 63 (2013) 726–737, https://doi.org/10.1016/j.enpol.2013.07.106.
[40] M. de Reuver, T. van der Lei, Z. Lukszo, How should grid operators govern smart grid innovation projects? An embedded case study approach, Energy Policy 97 (2016) 628–635, https://doi.org/10.1016/j.enpol.2016.07.011.
[41] C. Büscher, P. Sumpf, "Trust" and "confidence" as socio-technical problems in the transformation of energy systems, Energ Sustain Soc 5 (1) (2015), https://doi.org/10.1186/s13705-015-0063-7.
[42] L. Fuenfschilling, B. Truffer, The interplay of institutions, actors and technologies in socio-technical systems — An analysis of transformations in the Australian urban water sector, Technological Forecasting and Social Change 103 (2016) 298–312, https://doi.org/10.1016/j.techfore.2015.11.023.
[43] A. Lösch, C. Schneider, Smart-Grid-Experimente im Macht-Wissens-Dispositiv der Energiewende, in: S. Böschen, M. Groß, W. Krohn (Eds.), Exp. Ges., Nomos Verlagsgesellschaft, Baden-Baden, 2017: pp. 161–184. https://doi.org/10.5771/9783845285450-161.
[44] J.W. Meyer, B. Rowan, Institutionalized Organizations: Formal Structure as Myth and Ceremony, American Journal of Sociology 83 (2) (1977) 340–363, https://doi.org/10.1086/226550.
[45] H. Leblebici, G.R. Salancik, A. Copay, T. King, Institutional Change and the Transformation of Interorganizational Fields: An Organizational History of the U.S. Radio Broadcasting Industry, Administrative Science Quarterly 36 (3) (1991) 333, https://doi.org/10.2307/2393200.
[46] G. Möllering, Umweltbeeinflussung durch Events? Institutionalisierungsarbeit und feldkonfigurierende Veranstaltungen in organisationalen Feldern, Schmalenbachs Z betriebswirtsch Forsch 63 (5) (2011) 458–484, https://doi.org/10.1007/BF03372849.
[47] P.J. DiMaggio, W.W. Powell, Introduction. The new institutionalism in organizational analysis, in: W.W. Powell, P.J. DiMaggio (Eds.), New Institutionalism Organ, University of Chicago Press, Chicago, Anal., 1991, pp. 1–38.
[48] W.R. Scott, Institutions and Organizations, Thousand Oaks (2001).
[49] J. Battilana, Agency and Institutions: The Enabling Role of Individuals' Social Position, Organization 13 (5) (2006) 653–676, https://doi.org/10.1177/1350508406067008.
[50] R. Garud, C. Hardy, S. Maguire, Institutional Entrepreneurship as Embedded Agency: An Introduction to the Special Issue, Organization Studies 28 (7) (2007) 957–969, https://doi.org/10.1177/0170840607078958.
[51] P. Holm, The Dynamics of Institutionalization: Transformation Processes in Norwegian Fisheries, Administrative Science Quarterly 40 (3) (1995) 398, https://doi.org/10.2307/2393791.
[52] A.D. Meyer, G.R. Brooks, J.B. Goes, Environmental Jolts and Industry Revolutions: Organizational Responses to Discontinuous Change, Strateg. Manag. J. 11 (1990) 93–110.
[53] T.B. Zilber, Institutional Logics and Institutional Work: Should They Be Agreed?, in: Res. Sociol. Organ., Emerald Group Publishing, Bingley, 2013: pp. 77–96. https://doi.org/10.1108/S0733-558X(2013)0039A007.
[54] S. Bschorer, M. Kuschke, K. Strunz, Object-oriented Modeling for Planning and Control of Multi-energy Systems, CSEE J. POWER ENERGY Syst. 5 (2019) 10.
[55] M.Q. Patton, Qualitative evaluation and research methods, 2nd ed., SAGE Publications, Newbury Park, Calif., 1990.
[56] R. Razavi, A. Gharipour, Rethinking the privacy of the smart grid: What your smart meter data can reveal about your household in Ireland, Energy Research & Social Science 44 (2018) 312–323, https://doi.org/10.1016/j.erss.2018.06.005.
[57] VKU, Press Release, Gesetzesentwurf zur Digitalisierung der Energiewende "AUFWAND UND NUTZEN MÜSSEN STIMMEN", (2015).
[58] F. Engels, A.V. Münch, The micro smart grid as a materialised imaginary within the German energy transition, Energy Research & Social Science 9 (2015) 35–42, https://doi.org/10.1016/j.erss.2015.08.024.
[59] G. Möllering, G. Müller-Seitz, Direction, not destination: Institutional work practices in the face of field-level uncertainty, European Management Journal 36 (1) (2018) 28–37, https://doi.org/10.1016/j.emj.2017.10.004.
[60] H.Lerøy. Sataøen, O.A. Brekke, S. Batel, M. Albrecht, Towards a sustainable grid development regime? A comparison of British, Norwegian, and Swedish grid development, Energy Research & Social Science 9 (2015) 178–187, https://doi.org/10.1016/j.erss.2015.08.011.
[61] T. Lawrence, R. Suddaby, B. Leca, Institutional Work: Refocusing Institutional Studies of Organization, Journal of Management Inquiry 20 (1) (2011) 52–58, https://doi.org/10.1177/1056492610387222.
[62] D. van Doren, H. Runhaar, R.P.J.M. Raven, M. Giezen, P.P.J. Driessen, Institutional work in diverse niche contexts: The case of low-carbon housing in the Netherlands, Environmental Innovation and Societal Transitions 35 (2020) 116–134, https://doi.org/10.1016/j.eist.2020.03.001.
[63] R. Suddaby, T. Viale, Professionals and field-level change: Institutional work and the professional project, Current Sociology 59 (4) (2011) 423–442, https://doi.org/10.1177/0011392111402586.
[64] K.D. Elsbach, R.I. Sutton, Acquiring Organizational Legitimacy Through Illegitimate Actions: A Marriage of Institutional and Impression Management Theories, AMJ 35 (4) (1992) 699–738, https://doi.org/10.5465/256313.
[65] T.L. Galvin, Examining Institutional Change: Evidence from the Founding Dynamics of U.S. Health Care Interest Associations, AMJ 45 (4) (2002) 673–696, https://doi.org/10.5465/3069304.
[66] L. Vesnic-Alujevic, M. Breitegger, Ângela.Guimarães. Pereira, What smart grids tell about innovation narratives in the European Union: Hopes, imaginaries and policy, Energy Research & Social Science 12 (2016) 16–26, https://doi.org/10.1016/j.erss.2015.11.011.
[67] I.F. Ballo, Imagining energy futures: Sociotechnical imaginaries of the future Smart Grid in Norway, Energy Research & Social Science 9 (2015) 9–20, https://doi.org/10.1016/j.erss.2015.08.015.
[68] S. Wassermann, M. Reeg, K. Nienhaus, Current challenges of Germany's energy transition project and competing strategies of challengers and incumbents: The case of direct marketing of electricity from renewable energy sources, Energy Policy 76 (2015) 66–75, https://doi.org/10.1016/j.enpol.2014.10.013.
[69] G. Kungl, The incumbent German power companies in a changing environment: A comparison of E.ON, RWE, EnBW and Vattenfall, Universität Stuttgart, Institut für Sozialwissenschaften, Abteilung für Organisations- und Innovationssoziologie, Stuttgart, 2014 from 1998 to 2013.
[70] T. Pallesen, P.H. Jacobsen, Solving infrastructural concerns through a market reorganization: A case study of a Danish smart grid demonstration, Energy Research & Social Science 41 (2018) 80–88, https://doi.org/10.1016/j.erss.2018.04.005.
[71] W.R. Scott, Reflections: The Past and Future of Research on Institutions and Institutional Change, Journal of Change Management 10 (1) (2010) 5–21, https://doi.org/10.1080/14697010903549408.