Transforming power/knowledge apparatuses: the smart grid in the German energy transition

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Abstract:

Politics and the dominant actors in the German energy system fear that the politically promised integration of renewable energies in the course of the Energy Transition will lead to losses of control due to increasing volatility, decentralisation and heterogeneity of processes and actors. Yet, a novel form of control through the artificial intelligence of smart grids is envisioned that would tame the chaos in the system. To analyse the conditions and effects of smart grids we introduce the Foucauldian concept of a 'power/knowledge apparatus' into the study of sociotechnical transitions. It brings into focus the entwined changes of positions of actors, knowledge and power constellations and their effects. These are crucial to innovation and transformation processes, yet the question how they emerge is only marginally addressed in other STS approaches. The article analyses the problem framing and solution by smart grids as an emerging power/knowledge apparatus which implies a comprehensive re-arrangement of the power/knowledge constellations in the energy system. The order and ordering of the emerging apparatus of transformation is getting visible by an empirical case study based on expert interviews and document analysis. The apparatus aims at and engenders a permanent experimentation of all relations between the actors, organisations, techniques, knowledges etc., which are included in an energy system based on the envisioned smart grid.

Keywords: power/knowledge dispositif/apparatus, sociology of expectations, vision assessment, sociotechnical systems transitions, real-life experiments, energy transition, smart grid

1. Introduction[i]

'Securing a reliable, economically viable and environmentally sound energy supply is one of the great challenges of the 21st century. […] For these reasons, our present energy supply structures will have to be radically transformed in the medium to long term if we are to achieve energy security, value for money and the targets set by our climate protection policy. We will set the course so that the huge potential for innovation, growth and employment can be tapped as we revamp our energy system. […] In this Energy Concept, the German government has formulated guidelines for an environmentally sound, reliable and affordable energy supply and, for the first time, mapped a road to the age of renewable energy. The Concept is about designing and implementing a long-term overall strategy for the period up to the year 2050. […] In future, demand-side load management is to adapt energy demand more closely to supply. This calls for state-of-the-art intelligent grids and suitable incentives within the electricity pricing structure. These "smart grids" will manage

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1 *This is an Accepted Manuscript of an article published by Taylor & Francis in Innovation: European Journal for Social Science Research on March 16 2016, available online:* www.tandfonline.com/doi/full/10.1080/13511610.2016.1154783 *- page numbers as in the published version.*

electricity generation, storage, users and the grid itself using state-of-the-art information technology.' (BMU/BMWi 2011, 3, 19)

'The smart grid represents a vision of a future electricity grid, radically different to those currently deployed, where the bidirectional flow of both electricity and information allows demand to be actively managed in real time, such that electricity can be generated at scale from intermittent renewable sources. Delivering this decentralised, autonomous, and intelligent system represents a Grand Challenge for computer science and artificial intelligence research, and while its impact lies in the future, we need to start work today. […] Unlike existing grids where electricity generally flows one-way from generators to consumers, [the smart grid] will result in flows of electricity that vary in magnitude and direction continuously' (Ramchurn et al. 2012, 86-89).

The German energy transition ('Energiewende') has been called a risky experiment by observers and critical commentators in Germany and abroad. The goals of this transition – nuclear phase-out, renewable energies as substitution for fossil fuels – would imply a destabilisation of the established and mostly centrally controlled 'energy system' due to the volatility of renewables and more regionally distributed generators (e.g., Birnbaum 2011; Talbot 2012; Coats 2014). Looking at the introductory quotations one sees the so called smart grid presented as the solution to destabilisation and a loss of control. Such an envisioned smart grid would integrate the dispersed elements and functions and enable stability and control through flexible regulation. Behind this lies the vision of an artificial intelligence – as named in the second quotation – that promises flexible control despite the above named challenges. The basis of smart grids is seen as the massive implementation of information technologies in the energy system. Depending on the actual definition of a smart grid this might include novel internet technologies, smart meters, smart homes, electric vehicles and refrigeration systems as energy storages, smart markets for flexible charges or else becoming 'smart'. These are elements and components that would integrate all spheres of the sociotechnical energy system as a system of producers, consumers, markets, regulations, technologies etc. into a kind of energy internet. Many of the technological components under consideration have been in development even before the parliament's decision but their implementation in the energy system is largely a vision up to now. Such smart grid visions, however, are not confined to Germany but are a global energy policy idea, e.g. also in the U.S. or Denmark (Schick and Gad 2015). There have been, however, pilot projects and field experiments to test different smart grid designs for several years, already 450 in the EU (Covrig et al. 2014; also Nyborg and Røpke 2013).[ii]

A detailed view into descriptions and expert opinions on smart grids in the future and documentations of finished field experiments and their results reveal, however, that the realisation of smart grids does not only affect new technologies. Rather there is a need for novel arrangements of patterns of behavior of the involved actors and novel divisions of labor between them, novel forms of regulation and of markets. In short, a smart grid would affect all actors, elements and processes that constitute an energy system as a 'sociotechnical system' (e.g., Miller et al. 2013). The experiences of field experiments, in particular, show that in these it's not only novel technology that is being tested but novel arrangements of sociotechnical constellations or the need for their reconfiguration has been noticed (see chapter 3.2.).

Here, in our view, the emergence of a transformation regime is visible and can be analysed in present visionary discourses and experimental practices with smart grids, a regime that implies a fundamental restructuring of the societal constellations of power/knowledge in the energy sector. Along with the (envisioned) introduction of new technical components for a smart grid there are (envisioned) changes in potentially all actors in the system, their relationships amongst each other and the hierarchies in which they are involved. This concerns potentially all relevant actors, including the large energy suppliers, politics and regulation, industry and local actors such as municipal utilities and customers. Thus, to foster smart grids (generally: restructuring the energy system under new conditions of digitised control) coalitions of politics, the old central actors and novel actors (e.g. in renewable energy, IT industries) are testing and implementing novel constellations of power/knowledge which will also reshape their positions amongst each other.

These comprehensive re-arrangements of nearly all elements and relationships in the 'system' cannot simply be explained by answering the question: What are the elements, relations and processes which get re-ordered in such a process of transformation?[iii] Such re-arrangements imply changes in the positions between the actors, the weight of the relevant knowledge forms and modes of their production and of the power constellations, which are simultaneously changing with the re-arrangements of actor and knowledge relations. Therefore our central research question is, how are these re-arrangements going on and how are they being enabled? We argue that the concept of a *power/knowledge 'dispositif'* (apparatus) (Foucault 1978, 1980) is a suitable analytical approach, to understand and explain how the various elements and processes are being related to and how they influence each other in such re-arrangements. This concept brings processes into view which remain out of sight or marginal in other approaches, e.g. the multi-level-perspective (Geels 2005), yet are crucial to sociotechnical transformations (see chapter 2). How an apparatus is working, however, can only be explained through empirical observation, since it operates in historically emergent and specific ways. Therefore, we operationalise the theoretical concept in the case of experiments with smart grids, fostered by the vision of an artificial intelligence and the imperative to restructure the energy system. On the one hand, the case illustrates why the apparatus concept enables insights not only on what is changing in such complex transition processes, it makes visible how the changes are going on and are possible. On the other hand, only the empirical case can show that and how an apparatus is working which results in the emergence of a transformation regime.

The notion apparatus designates an order of and mode of ordering power-knowledge relationships in a particular area of society which is the instrument and the effect of a comprehensive historical strategy to solve the problems of a crisis. But such a crisis is not simply given as a 'necessity' of a transformation – such as the energy transition. Rather, an apparatus construes and constructs a crisis and transforms it into a problem that it offers to solve while at the same time contributing to an increased complexity of the overall transformative processes.

Seen as a technology in an apparatus, the smart grid vision promises to solve the problems of control of the energy system, induced by increasing decentralisation and heterogeneity of institutions, actors and processes of energy supply and consumption and the volatility of renewable energies, through artificial intelligence. Yet, in light of their societal conditions and requirements, the experimental practices of testing and implementing smart grids show re-arrangements of positions of actors, corresponding new power relations and new knowledge created in these practices. The order and strategy of the apparatus shows clearly in the emerging novel configurations of power/knowledge that afford changed and changing positions of all involved actors in the energy sector. The description and analysis of these processes with the apparatus concept enables us to grasp an emerging transformation regime and the new power/knowledge constellations it entails.[iv]

In the following we discuss Foucault's apparatus concept and show why it is important to explain how sociotechnical re-arrangements in the energy transition are going on and are enabled. We show second where and how this differs from and contributes to other Science and Technology Studies (STS) perspectives on the transformation of sociotechnical systems, real-life experiments and visions of the future. This discussion of the apparatus concept in relation to other approaches is followed by an exploratory empirical case study based on document analysis and expert interviews from which the insights into the workings of the power/knowledge apparatus were gained and strengthened. The case study illustrates the importance of the apparatus approach and, importantly, makes the operations of the apparatus visible. Following this we identify the paradox of the strategy of problem solution of the apparatus. This paradox lies in our case in the permanent experimental re-configurations of actors, institutions and processes which always destabilise the (emergent) power constellations in the energy sector. Yet, they are at the same time the condition of the desired transformation.

2. Analytical perspective and conceptual connections

Foucault's work has so far rarely been used in research on sociotechnical innovations and transformations (exception e.g. Manderscheid 2014; Tyfield 2014). This is surprising, because his analytical perspective is of great value for analysing ongoing transformations in complex power/knowledge constellations which in our view enable and produce the innovations or transformations of socio-technical systems, a central topic of STS research.

Foucault introduced the concept apparatus in his *History of sexuality* (1978) or, more implicitly in *Discipline and punish* (1977). In these studies he showed how in particular historical situations novel power constellations emerge simultaneously with new productions of knowledge and possibilities for regulation and action[v]. This happens through practices that produce new arrangements of heterogeneous elements, including amongst other things humans, artefacts, discourses, processes, institutions, mentalities and elements of knowledge. The resulting reorganisation in Foucault's studies is in relation to the requirements to discipline individuals and the biopolitical management of populations. Apparatuses aim at specific goals, e.g. the disciplined society or the controllable and economically usable sexuality, which shall be reached through various practices and institutions of investigating their possibilities, of self-management and state measures. Each apparatus thus has an 'ideal point' (Foucault 1978, 155), or an aligning idea, which substantiates its measures and processes.[vi] Yet, the goal is never reached. The practices that an apparatus entails lead to the identification and addressing of new practices. Insofar, the goal, the 'ideal point' is the cause and the effect of the apparatus. The unity of the apparatus lies in the shared relation of the very different elements and processes towards the one goal. Historically, apparatuses emerge in Foucault's reading in times of emergency and upheaval: An old power constellation is in functional difficulties, facing processes that it can no longer control and it posits as an imperative a goal that shall be reached (e.g. discipline yourself!, investigate sexuality!). In our case of the energy transition the imperative would for example be: become a smart user of the smart grid! The practices that are established and tested to follow the imperative, however, are of such nature that they consequentially eliminate the power that made them necessary. Foucault shows this in the removal of absolutistic power constellations through disciplinary power constellations which became so universal that they made absolutism superfluous (Foucault 1977).

Actually, Foucault's apparatus can be read as a perspective on emerging power/knowledge constellations in transformation processes and as a perspective on wide ranging power/knowledge constellations that affect whole societies, although, most often the latter perspective is focused on in readings of Foucault. This coincides mostly with seeing apparatuses as encompassing and long-lasting and as defining whole epochs, such as disciplinary power that laid the foundation for modern societies. However, we divert from this reading and use apparatus as a revealing concept for productive complexes of power and knowledge that can have different dimensions and times of operation. Apparatuses in our reading can be more diverse in extension and composition than often thought. In our case, the decentralisation of the energy system engenders practices of experimental power, visible in the smart grid case, which try to uphold the power of control of politics and energy suppliers but effectively transform it into novel constellations.

Therefore, the ideal point of this apparatus is the vision of the energy transition without any loss of control which shall be reached through practices and processes of changes of behaviour of actors, new distributions of roles, novel ways of communication, novel technologies and new regulations. All of which necessitate re-arrangements of established practices and processes. The general principles of these practices become visible in the case of the visions of future smart grids and the experiences made in their testing. Smart grids thus show the principle of a type of power which is new to the energy system and characteristic for the energy transition. The energy transition is thus the ideal point that installs the apparatus, substantiates it and continuously affords new measures for it. As a goal it is never reached but novel practices keep on emerging that transform the energy system and re-arrange its elements and processes due to the imperative of reaching the goal.

For analytical reasons, following Foucault, three dimensions of an apparatus can be discerned which together define it and highlight why a multiplicity of heterogeneous elements and processes should be analysed as an apparatus (see e.g. Foucault 1980; Rabinow and Rose 2003; Bührmann and Schneider 2008; Keller 2011).

1. The first dimension of analysis is the 'extension' of an apparatus. Therefore, we have to identify and to describe the *network* of all the relevant elements. In Foucault's words, the 'thoroughly heterogeneous ensemble consisting of discourses, institutions, architectural forms, regulatory decisions, laws, administrative measures, scientific statements, philosophical, moral and philanthropic propositions – in short, the said as much as the unsaid. Such are the elements of the apparatus. The apparatus itself is the system of relations that can be established between these elements' (Foucault 1980, 194). Empirically we identify these elements in the expert statements from interviews and documents. On this analytical level we are confronted with a net between human actors, things, knowledge, narratives, pasts, presents and futures. The array of elements and the individual elements themselves have to be considered in a temporal process of change.
2. Second, the identification of a common '*nature*' of the heterogeneous connections in such a net is of high importance to grasp its operational modes of producing power/knowledge constellations, its 'intensional' dimension. Guiding for this dimension is the question on how all elements of the net are connected in the same manner and which possibilities of their variation are enabled and/or constrained by this specific nature. These variations are central to the temporal dynamics of an apparatus. 'In short, between these elements, whether discursive

or non-discursive, there is a sort of interplay of shifts of position and modifications of function which can also vary very widely' (Foucault 1980, 195). This challenges us in our case to specify not only the common mode of connecting actors, techniques, regulations etc. in smart-grid visions and experiments; we are also called to diagnose the space of possible new forms of positioning between the elements in the whole energy system based on our findings on smart grid visions and experiments.

3. The third dimension of analysis is the *strategic function* of an apparatus. Foucault understands 'by the term "apparatus" a sort of […] formation which has as its major function at a given historical moment that of responding to an *urgent need*. The apparatus thus has a dominant strategic function' (Foucault 1980, 195). To get able to develop diagnoses on the processes of change of complex sociotechnical constellations we have to contextualise the identified net of elements and the common nature of its connections and variations in an overall societal or historical '*strategy*' of problem solution by means of changing existing power/knowledge constellations.

The apparatus concept does not only reflect what the changes in a heterogeneous network are but due to the nature of connections focuses on the establishment of a temporal strategy. The concept allows the examination of how new power/knowledge constellations emerge – or fail to emerge –through the re-arrangement of heterogeneous settings and their ways of operating. Therefore, it differs significantly from other STS approaches of analysing innovation and transformation processes and enriches their diagnoses. In the following we discuss central differences to the approaches of the multi-level-perspective, real-life experiments, the sociology of expectations and vision assessment in technology assessment), all of which have particular perspectives on processes of sociotechnical change.

Especially prominent in research on sociotechnical systems transitions is the literature of the '*multi-level perspective*' (MLP) on transitions (following Hughes 1983 and Nye 1990, e.g. Geels 2005; Verbong and Loorbach 2012). Sociotechnical systems and their transformations in this approach involve besides technological artefacts humans and organisations that design, produce and consume these technologies, economic structures, legal and other institutions, social norms and societal values, and much more. Accordingly, system transformations are seen as the restructuring of these elements in light of partly extremely stable, or locked-in, processes and structures that have grown for decades. The MLP points out that only 'protected niches' could be the space where radical innovations in such systems can emerge because here experiments can be done which are not compatible to the routines of 'regimes'. Furthermore, however, a transition would also involve changes on the 'landscape' level of societal discourses, global economic structures or other processes that transcend the level of regimes of sociotechnical systems and support the innovations in niches to be taken up in the regime or even establish a new regime.

Whilst this multi-level heuristic often works in historical descriptions of transformations, of which there are many in this literature, it has little to say about how reconfigurations in the complex relationships between the elements in sociotechnical systems take place and it has hardly any analytical grasp as to how such processes take place in the present[vii]. The apparatus concept favoured by us shares with the MLP the focus on heterogeneous complexes and their changes (dimension 1. above). But the apparatus approach focuses not mainly on the question what is changing in such complexes. Of main interest is the question of how the changes are going on and are possible. To explain the dynamics the Foucauldian approach brings into view the plays of power and knowledge and how they are productive of new realities and their orderings in practice. New qualities of creating and shaping relations are being strategically introduced in a political process of transformation that is not reducible to separate layers of reality, i.e. niches, regimes, landscapes (dimensions 2. and 3. of the apparatus). Below we discuss how visions of the future are crucial for such power to operate. Although, some research in the MLP points out the importance of visions in niches there is no thorough understanding of their workings and effects in the present (Weber 2003; Späth and Rohracher 2010; Verbong and Loorbach 2012, 13f). Thus, the apparatus approach goes beyond a weak common sense understanding of politics and power in the MLP, where power is typically seen as something which certain actors possess or lose (see footnote 5), as a property of regime actors stabilised through their position in the durable regime (see the critique of Tyfield 2014). The Foucauldian power/knowledge concept sees power, to the contrary, emerging and operating in the discursive and non-discursive relations within which actors are located and/or transformed. Such changes of power/knowledge constellations thus work as experiments, yet, not as the confined experiments in niches that the MLP would identify, but as experiments which affect whole sectors of society, as we will further discuss below.

The other research strand that shares some concerns with our approach is thus research on '*real-life experiments*' or 'real-world experiments' (e.g. for the Energy Transition see: Gross and Mautz 2015). The term real-life experiment is signifying experiments in society (outside the laboratory) as risky but indispensable enablers of innovation and governance in current modern societies. The concept in the sociology of science was introduced under the heading 'society as a laboratory' (Krohn/Weyer 1994; Krohn 2007a, 2007b). The intention of this research is to shed light on the fact, that the grand scientific and technological innovations in contemporary societies can no longer plausibly be explained by theories based on the division between basic research and applied sciences and technologies. Following their theory the experiment in society is the place of the production of new scientific insights and technologies, but at the same time, of society and its governance itself because of the embedding of the experiments in societal arrangements. This perspective highlights how real-life experiments are purposeful creative practices of knowledge production that transgress boundaries of established organisations or settings and that are open in their consequences. Here this is similar to the productive and experimental processes of an apparatus that enable new forms of knowledge in society. What the perspective on real-life experiments does not address is that the experimental production of knowledge simultaneously implies a reconfiguration of power relations in the societal sectors involved in the real-life experiments and that the simultaneous change of power and knowledge is an enabling condition for real-life experiments in the first place.

The condition of possibility of the success of an apparatus is its ideal point (e.g., 'energy transition') to which all processes refer. As an unattainable goal, as said before, it resides as a vision in the future that orients and substantiates the taken measures through which the vision shall be realised. A similar intuition has been guiding research on the role of visions of the future in innovation and transformation processes (e.g. Brown, Rappert and Webster 2000; Lösch 2006a, 2010; Adam and Groves 2007; Jasanoff and Kim 2009) of which we briefly point out two approaches. *The sociology of expectations* (e.g. van Lente 1993; Borup et al. 2006; Konrad 2006) has shown correlations between changes of visionary ideas, innovation practices and the expectations of actors involved in processes of technological development and innovations in a retrospective manner. The concept *vision assessment* in (German) Technology Assessment (e.g. Grunwald 2012, 2014; Ferrari, Coenen and Grunwald 2012; Lösch 2013; Böhle and Bopp 2014) shows the importance of assessing the contents of visions because they might besides technological development also orientate actions, political decisions and public perceptions of new or changing technologies in the present.[viii] Although we draw on these insights, the mentioned approaches have difficulties in relating their concepts to non-discursive aspects of sociotechnical processes[ix] and of investigating the relationships of knowledge and power. Now we show, how the apparatus approach can overcome these blind spots, conceptually and empirically.

Ideal points, according to Foucault, institutionalise ‘desire’ for them as a condition for success of apparatuses.[x] Similarly, the visions of the energy transition and more concretely of its attainability through the artificial intelligence of smart grids propel the experimental practices which initiate and enable the apparatus. Positioning visions as an enabling condition of apparatuses, we draw on the above quoted research strands to empirically and analytically grasp the workings of the outlined apparatus in its becoming. We want to explain why and how the apparatus is effective – or not – based on its ideal point; how the reference to the future enables the creative and powerful processes of re-arrangements through smart grid visions and practices. Visions in the present place contemporary processes and future, not-yet existing processes and developments into a shared context of meaning and normatively summon the practical use of these potentials. The efficacy of the ideal point – the energy transition, resp. the possibility of a controlled transition through the artificial intelligence of smart grids – should show in the experimental tests of smart grid designs. Real-life experiments can be seen as trials for realisations of visions. Three functions of visions are particularly important for the power of the ideal point:

1. Translation: On a factual level, visions and their ascertainment in prototypical designs of smart grids can be seen as translators or interfaces between present and future (e.g, Brown et al. 2000). Through this translation function smart grid visions can become hypotheses of real-life experiments. Oriented towards the general vision of an energy transition without loss of control, concretely envisioned prototypes of smart grids enable experiments. And experiences made in experiments might modify the envisioned concepts and specifications and create further need for experimentation. Visions and experiments co-constitute each other in practice and create a process of rearrangements in the whole energy system.
2. Media: On a processual level, smart grid visions can be analysed as communication media, following insights in own research on the mediality of visions (Lösch 2006a, 2006b). All involved actors have to refer to these visions irrespective of their standpoint or interests if they want to assess or justify their own or other’s measures to reach the goal of the energy transition. Shared visions in that sense enable communication between the different actors. Therefore, smart grid visions do not only initiate negotiations amongst actors but lead to results relevant for actions. The apparatus stays dynamic and open for rearrangements and creations through this function of the visions.
3. Coordination: Specified visions of smart grids can become a kind of guiding vision, a ‘Leitbild’, for a network of actors or an industrial sector and in turn orient and coordinate practices to reach it (cf. Dierkes, Hoffmann and Marz 1996; Böhle and Bopp 2014). Accordingly, one could say that the coordination function realises the unity of an apparatus in the course of the practices the coordinating function enables.

Through differentiating these three functions one can empirically observe the processes in an apparatus in real-time. Contrary to Foucault's own retrospective, historical use of the concept, with the help of the perspectives on visions we make use of it to investigate contemporary processes.[xi] The apparatus concept reveals how visions can have the function to establish new power constellations in a societal sector. Thus, the analysis of apparatuses that we undertake highlights emergence, creation and contingency and open-endedness of the contemporary processes that are being organised by an apparatus – the uncertain contestations of power/knowledge that are oriented towards an unattainable ideal point in the future.

3. The smart grid in the apparatus of the transition

This chapter presents the results and insights from our empirical research. Only through empirically specifying the historically emergent operations of an apparatus can we speak of *a specific apparatus* and make it visible. The empirical analysis is necessary to make use of the concept[xii]. Our empirical research involved an analysis of smart grid documents in policy and scientific discourse and exploratory expert interviews with German energy and smart grid experts. After describing the empirical basis and method we present the results along the dimensions of analysis for apparatuses discussed above: the ideal point, the network, the 'nature' and the strategy of the apparatus.

3.1. Method: document analysis and expert interviews

Our empirical work consisted of a document analysis and qualitative expert interviews.[xiii] For the document analysis we considered policy documents on the energy transition and smart grids mainly from Germany but also from the U.S. issued between 2007 and 2014. Furthermore, scientific texts on the technologies of smart grids from 1997 to 2014 were included. Besides the definitions of smart grids we searched for the articulations of technical and societal expectations and implications which are explicitly and implicitly articulated in the texts. The document analysis resulted in the reconstruction of the core ideas of dominant smart grid visions.

Besides this, we conducted a series of qualitative expert interviews in 2013. These included experts from power supply companies, an association of local utility companies, an industry association, an environmental association, a consumer protection association, technology companies, and scientific, especially economic experts. One of our criteria to choose the experts was their involvement into smart grid field projects. The other was that the experts were representatives of constitutive organisations of the German energy system. This selection of heterogeneous experts was based on the expectation to get different perspectives of the societal implications of future smart grids and of the ongoing processes of systemic change. In the interviews we asked the interviewees to outline their understanding of the 'energy system' and how it might change in the future, what present challenges they saw and how they thought of smart grids. We also included questions that made them assess their organisation's actions from their standpoint in relation to their perception of the transformation. We used the interview situation to lead the experts to produce 'their' vision of the future system. All the specific questions concerning their evaluations and estimations of the outcomes of the smart grid experiments, the present energy system, control and security, the changing role of markets, regulations, suppliers, consumers, politics and the media were linked to these visions. Surprisingly, we identified more convergences in the discursive statements of the experts concerning experimental demands than differences which could be expected because of the different positions and perspectives of the experts in and on the transforming energy system.

3.2. The ideal point operationalised: smart grid visions

As we argued above, the ideal point of the apparatus is the abstract idea of a controlled energy transition. However, one way this is being operationalised in the apparatus and ascertained in practices is through the vision and ideas of smart grids; smart grids shall be realised to fulfill the larger goal of the transition. Based on the document analysis we can conclude: The so called 'smart grid' is mainly a technical vision of engineers and IT experts and is one of the core ideas of the transformation of energy systems. The smart grid is an engineered vision and reaction to the transformations of energy systems. It addresses from a technical point of view the increase in varieties of energy production and consumption, the volatility of renewable energies and the need for uninterrupted supply of energy. Roughly, one can say the smart grid shall automate the energy system with the help of information and communication technologies and thus create an adaptive and self-organising energy system. Different to the existing centrally controlled one-way system which transports energy from particular sites of production to particular sites of consumption, the smart grid shall enable two-way flows of energy and information with sites of production and consumption changing in a decentralised system. These changes can be induced by natural conditions (e.g. sun not shining) or changing demand or production of energy. Yet, they shall be simulated and controlled with algorithms that keep the system in balance and energy available, e.g. through 'intelligently' telling certain system elements to consume less energy if there is less available. The smart grid vision builds upon ideas of internet like networking, ubiquitous computing and artificial intelligence and envisions a thorough coupling of energy and information flows. This common structure and argumentation can be exemplarily found in the quotation of Ramchurn et al. (2012) that we quoted in the introduction (see also Orwat 2011; Büscher and Sumpf 2015).

But historically seen the vision of a smart grid is not an invention made in the course of political decisions worldwide on Energy Transitions. The smart grid vision started in the 1990s in engineering circles (cf. Vu, Begouic and Novosel 1997). By the mid-2000s the vision has entered policy in the US and EU and first smart grid research and experimentation projects were launched across the world. In the EU, more than 450 smart grid projects have been started since 2002 seeing a significant increase since 2009 (Covrig et al. 2014). Because of these heterogeneous projects by now, one cannot speak of a single smart grid vision anymore. Beyond the most general idea to make the electricity grid 'smart' and increase its automation, there are many different ways how this is imagined and being practically worked on in concrete smart grid projects: there are numerous smart grids in the making (e.g., with or without smart meters in private households, with or without electric vehicles as energy storages; see BMWi 2014; Skjølsvold and Ryghaug 2015[xiv]).

But beyond the differences and dynamics of smart grid visions and projects in detail, the implementation of the principles depicted in smart grid visions in the sociotechnical energy system imply much more than new technical designs. The realisation of the vision implies a far reaching and multidimensional sociotechnical transformation not only of technologies but also of actor, knowledge, and power constellations. With the smart grid visions social changes are envisioned – for example consumers turning to prosumers, new forms of markets, novel business models and sustainable everyday practices.

Each of these changes are involving radical changes in everyday routines. Thus, by now, also from engineers' perspectives, the 'social factors' are increasingly seen as more challenging than the 'technical' aspects of smart grids (cf. Covrig et al. 2014, 11). But what does this call for attention on social factors imply for our analysis?

The smart grid vision may not be the only operationalisation of the ideal point of the apparatus that we are investigating. But this vision ascertains the opaque and abstract idea of a controlled energy transition into a more specific and 'technological' framework and this is an important effect on power/knowledge relations. Smart grid visions have an important translation function since they put an indeterminate future into concrete technological measures to be realised, they connect the not-yet to the present with specific steps that can and should be taken to foster a particular version of the future. Through being relatively concrete in terms of technologies and processes the smart grid vision furthermore addresses particular actors (e.g. IT industries) as competent for solving problems. Yet, it also becomes a medium of communication for all those who 'speak' about and with this vision to others and therefore its effects are also the contested circulations of this particular way of imagining the future of the 'energy system'. Along with its force, which is amplified by the massive processes of digitisation, the smart grid vision enables and coordinates practical experiments to create positions of actors, knowledge (including technologies) and power constellations with the aim to 'smarten' the energy system. Besides this visionary discourse, what is the actual formation of the apparatus? In the following sections we develop which role the operationalisation of the ideal point of the energy transition by means of the smart grid visions plays in the apparatus.

3.3. First dimension of the apparatus: the network of 'old', 'new' and 'not-yet'

In the network dimension we designate the extension of the apparatus based on the elements that are mentioned in the interviews and documents as being important factors of the current and future energy system. There is heterogeneity in character in the network: discourses, artifacts, institutions, practices and so on are being included. Furthermore, and important for the apparatus, there is temporal heterogeneity in the network in that there are 'old', 'new' and 'not-yet' implemented elements. As 'old' we designate elements that have been in the 'energy system' for decades and have become routines and almost taken for granted in the eyes of the experts. Here the experts think of the big energy suppliers with their fossil and nuclear power stations, routines of consumption that were established in the 20th century, the structure of power grids, governance agencies, municipal utilities, certain forms of research and development and so on. As 'new' we can designate elements that are said to have recently entered the system. Furthermore, these elements seem to have a kind of catalysing function for change, they bring a new pattern with them. Most significantly here are renewable energies. Yet, these are said to be accompanied by novel laws (e.g. the German 'Renewable Energy Sources Act')[xv], prosumers who are producing and consuming energy, experiments in the field and in the parliamentary decision for the energy transition. Finally, there are elements in the network mentioned that are 'not-yet' fully existing in the system; they are being imagined or experimented with in confined settings. These are mainly smart grid technologies and their respective governance and regulation. Furthermore, other not-yet elements that are being connected in the network are a large number of electric vehicles or new service providers and new business models.

This structure of temporal heterogeneity was highlighted in our interviews. As our interviewees pointed out, it has been a central challenge to connect old, new and not-yet existing elements in such a way as to produce a resonance between them. It was the coming together of these different elements that produced experimental settings which created new knowledge. For the creation of such experimental settings, however, visions of smart grids were crucial. These visions enabled the experiments in the first place by producing interfaces between existing and not-yet existing elements. In this translation function, visions showed the need for experimentation, they coordinated experiments and they highlighted or even produced novel possibilities for connecting and changing elements.

3.4. Second dimension of the apparatus: experimentation as the nature of the connections

From experiments to becoming experimental

Besides tracing the heterogeneous elements that form the relevant network, in our apparatus analytical reading there are a particular 'nature' to the connections in the network and systematic possibilities of their variation observable. This nature of connections in the network that we can identify in the statements of the experts is experimentation with control through digitisation[xvi]. But experimentation does not only concern experiments with novel technical designs or artifacts. Rather, the process consists of experiments with whole sociotechnical arrangements in the simultaneous creation and testing of knowledge, positions of actors and power constellations which shall enable the implementation of digitised control settings which are perceived, through the smart grid vision, as novel and supportive of the energy transition. When addressing this experimental nature of the connections between the elements of the network it becomes clear in the argumentations of the experts that they do not refer only to one experiment or only the official field experiments (e.g., E-Energy pilot projects). They articulate multiple experimental situations and processes on different levels of the energy system which are in relative autonomy, yet partly depend on each other. These experiments have differing logics, designs, structuring effects, powers and forces. We could trace articulations of regulation experiments, market experiments, prosumer experiments, grid operator experiments, communication experiments etc. Results and experiences made in one experiment seem to lead to the identification of further and other experimental needs.

In the following we show by means of descriptions of the transformation processes from our expert interviews, how the 'becoming experimental' of the sociotechnical arrangements is taking place according to the experts' observations; and how in this process of experimentation the simultaneous creation and testing of knowledge, positions of actors and power constellations get articulated.

New knowledge, new positions of actors, new modes of power

From the perspective of a representative of an established and large energy supplier experimentation is seen as follows. A R&D manager of one of Germany's four 'big' energy suppliers describes the key insights from experiments with smart grid technology in a smart grid pilot project. After saying that the experiments were crucial for 'practical' learning, he refers to what was learned:

'The main insight was that we basically have the technical components, but that we face limits of profitability. A main barrier is a lacking legal framework [...] The first surprise was how difficult it was to make customers participate. We had to explain endlessly what we want to do to inform customers why we wanted them in the field test. For us the system and the related

changes were relatively clear, it‘s obviously not clear to the customer out there. Even business customers haven‘t understood it until now, well the topic flexibility, that‘s a way of thinking that is not there at all. [...] Those who participated were actively engaged, they actually showed flexibility' (Energy supply company 2013).

Although the dimensions of the creation and testing of knowledge, positions of actors and forms of power are deeply interrelated in this exemplary quotation, we can analytically separate three effects of experimentation:

1. What was the new knowledge that was created and tested? First, the experiments showed him, that the tested technologies worked – if seen separated from their social embedding. Thus, his main insight was that the tested technology faced economic and social constraints, which opened the issue of regulation and legal frameworks and the whole sociotechnical field of routines of consumption, market prices, existing technologies, values and knowledge of customers.[xvii]
2. This led to the second main insight, that the relation to the customers was peculiar as well. Customers first had to be convinced to participate in the field tests. They had to learn about the smart grid ideas and the relevance of testing them which caused the supplier to identify the issue of communication as central to its pilot projects which needed 'real' households. The knowledge thus transformed points to a change in positions of actors or in the way of addressing existing actors. Whilst the manager still presents the supplier as the knowing and central actor to whom the 'changes were relatively clear', there are openings in the configuration of actors. First, the supplier is forced to learn and to experiment, to change its way of doing business and research and development. Because, second, now there is the need to radically involve customers in the highly interactive arrangements of 'smart' technology which run according to a different paradigm than the one practiced for decades. There is a new role for former 'customers'. Now, customers need to become 'co-experimenters'[xviii] who participate in the testing and creation of smart grid arrangements. This position, however, is also new to customers who were difficult to involve and still have the old 'way of thinking'. There are, however, people, who were willing to fill this position of co-experimenter, who 'actively' participated and 'showed flexibility' in their consumption of energy. Co-experimentation doesn't take place in the laboratory but at home or in the factory and thus needs the opening and changing of habits and routines of consumption.[xix]
3. The issue of co-experimentation points thirdly towards the changing power constellation of these re-arrangement processes. Whilst there are still issues of classical regulation which are not conducive to profitable smart grid arrangements, a deficit of the old power constellation, there is a whole other new dimension of governing the customers in their role of co-experimenters. Communication, convincing through argument and supporting other ways of thinking are now tasks that are demanded by actors used to 'old' forms of top-down government. Furthermore, in the statement of the manager one can trace the rising power of the customers in governing smart grid experiments. In a way, the intended technical interactivity is subject to a heightened interactivity between actors in the system.

Governance and regulation are becoming experimental

A recurring theme in our interviews is thus that governance and regulation, i.e. the steering of the transition and its experiments, itself are becoming experimental. This is of particular interest for the apparatus analysis, because modes and institutions of governance and regulation can be seen as sedimentations or representations of a certain power constellation. Even in relation to classical governance by policy making and law, another of our interviewees stated:

"We're experimenting with the regulatory framework. […] That was the same with the E-Energy projects. It wouldn't have been possible with the existing regulations to do what they did in the project. They got a derogation by the federal grid agency. […] How can we create pilot projects, but without violating laws?" (Economist/academia 2013)

On the one hand, according to his statement, regulations need to be found which allow experimentation without violating other regulations that were made to create stability and responsibility in the system. It is worth mentioning here, that many projects (here in the case of E-Energy) could only experiment due to a special exclusion from existing laws. On the other hand, and this is the more difficult aspect to it, regulations shall encourage experimentation and help create experimenting actors.

Concerning the relation between old and new modes of governance a spokesperson of a consumer protection agency refers to the new power of decentralised and regional governance and the delegitimisation of the 'old' and centrally coordinated and regulated energy system:

„According to the results of the field tests [...] one should conclude that a mass rollout of [smart grid/smart meters] is not a good idea. Rather, more work to convince people is necessary [...]. You have to tell stories. One should communicate that the new system is called renewable energies, and they only produce when nature allows it, they have a different regional distribution. We have to take care that there is energy supply if the renewables are not running. There is a completely different basic structure in the system and a regional responsibility and I think that is not yet properly communicated" (Consumer protection association 2013).

Similar to the energy supplier above, the new knowledge gained by the expert from the consumer protection association concerns the issue of governing the transition. The statements converge in the point, that there seems to be something wrong with the present governance of the experimental process. The old strategy of centralised regulation and implementation of smart grid technologies seems to not work. Instead, one seems to need further legitimisation for the changes which shall be reached through convincing people with proper arguments. This insight is based on an underlying shift in the workings of a changing energy system which affects the mundane routines of energy and of conceiving the responsibilities and actors involved. Here a new power constellation is seen in parallel to a changing technological structure.

There is thus also a shift in positions of actors. The former governors of energy, industry and politics, can no longer rely on routine ways of governing. New actors come into the play of regulation in the energy system: citizens. Since the changes are not simply 'inside' the workings of the established energy system, people need to become actively involved in the transition. What the spokesperson from the consumer protection agency thus demands is a change in the form of governance. Mass roll outs, classical top-down government doesn't work, one has to 'tell stories' which embed local changes into an overall change of the system and its imagined demands. Power needs arguments and proper argumentation to involve people. There is, however, ambivalence in this account. Whilst his argumentation in the interview implies a certain communicating agency which speaks to the people, communication from the beginning is a two-way process. Along with the regional responsibility comes regional power. One can therefore also read this passage as a sign of a complex situation in which it is not clear how to communicate, but rather, that there seems to be something wrong with communication. Citizens and governing bodies have to find a way to properly communicate with each other. There is still a 'gap' between experts and users and citizens. Thus, governance and communication are turning experimental.[xx]

Such experimental governance is more explicitly addressed by an industry association How you enable experiments through regulation is itself an experiment:

„You have to change the legal framework in such a way that the grid operator can do research and development [...], but also take risks, respectively that their perspective is not just the reduction of expenses and not just the avoidance of risk" (Industry association 2013).

Whilst the interviewee refers to classical governance and regulation by law, what he would like to see as a consequence is the (re-)forming of the subject 'grid operator'. The objects of governance here are at first sight the many local grid operators, the municipal utility companies (of which there are many in Germany) which distribute electricity locally to consumers. For decades, following the expert, these companies have been running a stabilised system within a tight legal framework that emphasised security and stability: experimentation and digitisation were none of their business. Now, however, the interviewee describes a time when innovation and with it risk taking has become necessary – even for established players in an established system. What he thus says is also necessary is to turn grid operators into co-experimenters; those who haven't been innovative shall (or must) become innovative now to take risks and experiment with smart grids. Similar to our first quotation by the big energy supplier, it is a question of a change in actor positions here or rather a new actor position opening up that needs to be filled. Whilst above the consumers should become co-experimenters, here, the local grid operators shall similarly actively participate in a larger experiment of making grids smart.

The creation and testing of knowledge plays a crucial role in this envisioned governance. First, this is the prime object of governance to which the making-experimental of the local grid operators is only a means to start the experimentation. But second, knowledge is a means of governance here. Later in the interview, the expert from the industry association refers to his organisation's task of distributing knowledge about the results of the smart grid experiments to the local grid operators. In his view, it is crucial that most of these operators start experimenting, it won't be enough if some 'avant-garde' operators experiment and the others don't. Therefore, what he envisions is also a lively exchange between grid operators to foster learning and risk taking and his association shall contribute to making this exchange happen.

Experimentation as the universal norm of the apparatus

What the above mentioned interview passages have been getting at from different angles is summed up by the following quotation from an expert of an environmental association:

„Now we're arriving at a certain stage where we want to turn the whole system upside down. There is an infinite number of actors that have to be included into the system. And if we don't

get acceptance now, the system will collapse. […] In the last 15 years this wasn't a problem, but now it is. […] It's important to conduct field tests to see how one can reach the customers and whether they want it at all." (Environmental Association 2013)

In this statement a shared estimation of all the experts concerning the need and demands of the energy transition is articulated very clearly. The energy system is in a process of change which affects all dimensions and elements of its arrangements – at the same time techniques, actor behavior, modes of communication and regulation.

Taken together, the expert's statements show that there is the shared new knowledge of a necessity of new constellations of all actor positions, power and knowledge production in the whole complex. The possibility of this sociotechnical change is seen by the experts in various re-arrangements that create experimentation and heterogeneous experimental practices that re-arrange existing structures towards 'smartness'. The experts are interpreting the changes and experimental demands as a situation of being in between a destabilised old constellation and an open not yet existing constellation of the future. They designate specific experimental demands in relation to anticipated futures, which are communicated in the form of smart grid visions – this is the translation function of the visions. Without such an ascertainment of the abstract idea of a controlled transition in the smart grid vision it would not be possible for them to decide which movements or dynamics are really functional elements of the transition or an unimportant environmental dynamic outside the 'energy system' that they imagine. Secondly, the smart grid vision enables communications amongst the experts, yet they define this vision, its implications and demands differently from their particular standpoints. Thirdly, the deducted demands coordinate experimental practices without a central coordinating agency since there is a shared consensus of the necessitiy for experimentation.

But in the statements we also see the articulation of a massive dynamic of change, which implies a multitude of uncertainties, opportunities and possible risks. In this flux, experimentation is seen as the central viable solution to shape a process of transition in heterogeneous experiments. This demand is being articulated in the realisation of the absence of a central control agency for the experiments. Co-experimentation between all actors is seen to be of growing importance and needs to be fostered in the eyes of the experts. Thus the experimental challenges in multiple dimensions can neither be confined to local official field experiments or pilot studies nor to technical trials. The experiments are experiments of re-arranging complex sociotechnical constellations with different logics and ways of experimentation. Therefore, in all the interviews the experimental needs are articulated as an imperative – 'become experimental!' – and only with vague hints of how this might be accomplished. Becoming experimental is therefore the sought-after mode of practice which produces and re-produces the apparatus and its effects, it is the goal and the means to reach it. Within the apparatus becoming experimental is the central effect of its power, the measure of its success or not. It is furthermore the 'universal'[xxi] norm, as seen from within the apparatus, to produce and order inclusions and exclusions into the re-arrangements that the apparatus is also producing. Central to the power/knowledge effects of the apparatus are its trials to impose a particular transformative knowledge practice: the experiment.

3.5. Third dimension of the apparatus: a strategy for an experimental regime of transformation

The first dimension of the apparatus analysis allows us to understand the extension of the emerging apparatus (the articulated connections between the old, the new and not yet elements). In the second dimension we can identify experimentation as being the common nature of the inter-relational changes, which makes changing constellations possible in the first place. Furthermore, on the third dimension of the apparatus analysis we can reconstruct an overall strategy of problem solution behind the discourses and the practices that entangle with them. This strategy shouldn't be understood as an intended or planned strategy of a confined number of actors of the energy transition – such as the German government or the big four energy suppliers. Rather, it is a strategy that creates and establishes new constellations of power[xxii]. It is an emerging strategy, which develops in the course of the heterogeneous changes of the net and in reaction to the crisis of which this net is a part. This strategy is an explanation of the coherence between all the singular observations. It also explains the emergence of the apparatus made possible by an old power/knowledge constellation that it undermines through permanent experimentation and changing responsibilities.

The problem of the German energy transition, as it is framed, enacted and addressed by the apparatus, can be described as follows: The desired and politically declared integration of renewable energies necessitates far reaching transformations of many sociotechnical arrangements existing and institutionalised in the energy sector which are thought to be controlled with smart grids. But the strategy to solve this problem can be characterised as follows: The re-arrangements that smart grids necessitate between actors, regulations, technologies and knowledge flows require heterogeneous and ongoing experiments with digitisation in all of the relations in the arrangements to establish a new constellation of power. The apparatus, through offering its 'solution', makes only a particular problem visible – problem and solution are simultaneously being produced by the apparatus. But that is not enough: All the observed experiments and detected demands for new experimental measures are not only seen by the experts as being means to enable the transformation process; interestingly, they seem to be also the goal of the transformation. If we think the experts's assessments through, the arrangements of future energy systems, which they anticipate, would demand to permanently experiment with modes of knowledge, new technologies, actor behavior and the creation of new power constellations. Permanent experimentation is the means and the end of the strategy. It still remains an open question if the experiments are seen as the central mode of the new energy governance of future energy systems, or of a transformation regime that shall become established.[xxiii]

Taken together we can describe the emerging strategy of problem solution as ongoing replacements of elements and structures of centralised, exclusive and routinely running energy regimes through the plurality of decentralised, inclusive and experimental regimes of transformation. This doesn't mean that the emerging transformation regimes are more democratic than the present system, it only points towards strongly changed constellations of knowledge and power which govern the processes of transformation. We can characterise this as an ongoing production and testing of sociotechnical arrangements that have to enable flexibility, risk taking, learning and self-regulation instead of controllability through predictability. And these productions, paradoxically, need their contrary: the imagination of controllability, predictability, risk-avoiding and so on, in order to cause the ongoing demands for getting experimental. The operationalisation of the vision of a controlled energy transition through the artificial intelligence of smart grids opens up the space and horizon for experimental needs but only because they are placed as being the contrary of the present situation: the future beyond the transformation. And the means to try to reach this future is the apparatus that we described, although its effects are subversive to the power constellation that brought it into being.

4. Conclusion

We started with the observation that politics and dominant actors of the German energy system and the mass media articulate fears of a loss of control which is based on the integration of renewable energies, decentralisations and increasing heterogeneities of institutions, actors, things and processes. And this, according to our analysis, is a framing of the problem which is enacted and addressed by a power/knowledge apparatus emerging in the course of the energy transition. The envisioned solution of the problem through a smart grid implies experimentation with control through digitisation. This demands permanent experimental re-arrangements of all sociotechnical arrangements of the energy system and its power constellations. Such experimentation is the instrument, effect and condition of success of the apparatus that we analysed. So the emergence of an experimental transformation regime can be explained as the effect of a power/knowledge apparatus. We introduced the Foucauldian concept of power/knowledge apparatus into the study of sociotechnical transitions since it brings into focus such entwined changes and effects of positions of actors, knowledge and power constellations. These are crucial to innovation and transformation processes, yet the question of how they are enabled and engendered is only marginally addressed in other STS approaches.

Our empirical analysis based on expert interviews and document analysis highlighted the shared ‚nature‘, the order behind the possibilities of changes of positions in the net, of the elements that constitute the apparatus. Accordingly, experimentalisation for the sake of digitisation, the testing and learning about new combinations of elements is the foundation of what is referred to as ‚smart grid‘ and this involves much more than novel technological artifacts. We showed how smart grids are measures to reach the promise of control within the energy transition and how concrete smart grid visions become the hypotheses of experimental designs. This co-constitution of anticipatory knowledge and real-life experiments shows the permanent re-arrangements.

The analysis of the apparatus highlights a strategy along with which a new constellation of power relations is emerging in the energy sector. Instead of the promise of the vision of the energy transition this is not characterised by a new centralised control in the form of artificial intelligence but as an experimental power constellation which is based on the permanent creation and testing of novel options. This disperses the power to transform arrangements amongst different actors, things, institutions and processes. At the same time, however, a pressure develops for everyone involved to become reflexive, flexible, risk taking and responsible. As we said before, the apparatus produces the necessity for conscious co-experimentation. This, however, is not a democratisation of these experiments in an emancipatory sense. The apparatus subjects everyone involved to its imperative ‚become experimental!‘ and includes and excludes based on this demand. Furthermore, the apparatus entails a paradox: based on the permanence of experimental re-arrangements, even novel arrangements produced within the apparatus might come into question and be re-arranged.

The genesis of the apparatus that we analysed is thus not a linear and determined process. An apparatus produces inclusions and exclusions; it enables and constrains possibilities by modifying the relations between the elements of the involved sociotechnical arrangements. Its success – or not – influences the further historical emergence of the apparatus itself, its further directions of unfolding. The Foucauldian perspective on apparatuses brought into view power/knowledge constellations and their ways of operating and helps to address transformations and innovations in sociotechnical systems as far reaching societal, political and cultural reconfigurations – which are often out of focus in other research on sociotechnical transformations. The particular forms of in-/exclusion of the experimental apparatus that center around smart grids have to be more thoroughly researched and potentially also challenged. There are diverse options for where and how 'smartness' of the arrangements is enabled and practiced and this is not only a technical question (see also Kourtit and Nijkamp 2012). Further research is needed to elaborate in more detail and on different levels of observation on the effects of the power/knowledge transformations for which we could only open the perspective through our exploratory analysis. How exactly do actors in this apparatus act? How is knowledge being produced and used? And what do the contestations of and within this emerging power constellation look like? Such would be questions that guide further research into smart grids and transitions following the Foucauldian lens that we argued for.

Furthermore, although we identified the smart grid as an important, if not the core, element in the apparatus leading to a transformation regime, it is not a dictate. The strategy might fail, the tools to reach its goals might be transformed and smart grids might disappear altogether. This, however, will also depend on the relationships and contestations that the apparatus that we analysed will create with and face from other emerging or established apparatuses. Co-experimentation in its diversity can have partly more democratic and partly more technocratic shades. The question remains, however, how exactly this will play out. It is unlikely that experimentation will be challengeable in contemporary times of transition but smart grids as a concrete trajectory in the apparatus are challengeable, they are not an inherent constraint but a contested and contestable force. And here lies the value of the analysis of the apparatus that we undertook. It is a measure for observation that is neither a retrospective explanation of past transformations, nor a prospective imagination of the future of transformations. Instead it helps to identify the contemporary and ongoing formation of possibilities and impossibilities of transformative power constellations.

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Quoted Interview-Partners (anonymised)

(All interviews were made in spring and summer 2013)

Consumer Protection Association / NGO (2013) = spokesperson of a German consumer protection association

Economist / Academia (2013) = economist from a German University department

Environmental Association / NGO (2013) = leading expert for renewable energies from a German Environmental Association

Industry Association (2013) = expert for smart grids, smart markets and regulation from one of the big industry associations in Germany in the energy sector.

Power Supply Company (2013) = head of an innovation group of one of the big German Energy Supply Companies.

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i We thank our colleagues Knud Böhle, Stefan Böschen, Patrick Sumpf, the journal's editor, Thomas Pfister and two anonymous reviewers for their feedback to this text. The empirical research for the analysis was undertaken as part of the Helmholtz Alliance 'Energy Trans' (www.energy-trans.de).

ii 'The smart grid' is thus actually a huge variety of different ideas and experimental designs of 'smart grids' (Engels and Münch 2015; Goulden et al. 2014; Skjølsvold and Ryghaug 2015). One of the most prominent and regionally distributed field experiments with smart grids in Germany was the program 'E-Energy'. E-Energy was a consortium which tested the implementation of smart grid designs in different pilot projects in six regions of Germany (B.A.U.M. 2012; BMWi 2014). The project E-Energy took place from 2007 until 2013 and was a federally funded R&D project involving industry, research and municipalities (www.e-energy.de, accessed 30. Sept. 2015).

iii This is the typical question that is being asked by research on sociotechnical systems and transitions of these systems (e.g., Hughes 1983, Geels 2005). See also our critique of these approaches in chapter 2.

iv If we speak about 'power' in this paper, we follow Foucault's definition of power in *History of Sexuality, Vol. 1:* '[P]ower is not an institution, and not a structure; neither is it a certain strength we are endowed with; it is the name that one attributes to a complex strategical situation in a particular society. […] Power is not something that is acquired, seized, or shared, something that one holds on to or allows to slip away; power is exercised from innumerable points, in the interplay of nonegalitarian and mobile relations' (Foucault 1978, 93-94). Three dimensions of his power conception are mainly important for us: the 'multiplicity of force relations immanent in the sphere in which they operate', the character of 'support which these force relations find in one another, thus forming a chain or a system' and finally the overall 'strategies in which they take effect', e.g. 'in the formulation of the law, in the various social hegemonies' (92).

v see also on the analytical value of the apparatus concept Rabinow and Rose (2003, 9).

vi This can be bodies to be disciplined or the sex which needs to be investigated and domesticated. ‚Sex […] is doubtless but an ideal point made necessary by the deployment [apparatus] of sexuality and its operation' (Foucault 1978, 155).

vii As Büscher and Schippl (2013) point out, it is still highly unclear how exactly relationships between the heterogeneous elements in the presumed sociotechnical systems are enabled and how they function.

viii In addition the debate on 'visioneering' (Mc Cray 2012; Nordmann 2013; Schneider and Lösch 2015) as active and strategic processes for influencing and steering innovation- and transformation processes connects the research issue 'visions' closely to processes of future making through design.

ix In the project 'visions as socio-epistemic practices' we enlarge this focus to understand the practical effects of visions in innovation and transformation processes (http://www.itas.kit.edu/english/projects_loes14_luv.php; accessed 30. Sept.2015).

x ‚By creating the imaginary element that is "sex," the deployment [apparatus] of sexuality established one of its most essential internal operating principles: the desire for sex – the desire to have it, to have access to it, to discover it, to liberate it, to articulate it in discourse, to formulate it in truth.' (Foucault 1978, 156)

xi Manderscheid (2014) and Tyfield (2014) similarly try to reorientate Foucault's analysis towards a real-time analysis of sociotechnical change.

xii As is the case in Foucault's studies which always entangled empirical material with theoretical reasoning.

xiii The empirical work was conducted within the research project ‚Systemic risks in energy infrastructures‘. This project is one project of the Helmholtz alliance ‘Energy-Trans’ (http://www.energy-trans.de/english/68.php; accessed 30. Sept. 2015).

xiv See the huge variety of smart grid prototypes realised in E-Energy (BMWi 2014; www.e-energy.de; accessed 30. Sept. 2015).

xv The “Erneuerbare-Energien-Gesetz” (Renewable Energy Sources Act) in Germany is said to establish a decentralised logic of power generation from renewable energy sources against the prevailing centralised logic.

xvi Digitisation has to be considered as the latest step in what Beniger (2009) called the 'control revolution' unfolding from the 19th century onwards to coordinate the increasing complexity of sociomaterial processes in industrial societies. Digitisation, understood as an ongoing process, establishes and transforms relations amongst subjects and objects and the sociotechnical ecologies that they form together. It thus also changes the subjects and objects and the forms of coordination between them (Hörl 2013; Thrift 2011).

xvii This perception of our interviewee is in accordance with the results EU research on smart grid projects which also showed the high uncertainty concerning the social side of smart grid innovations (Covrig et al. 2014, 11).

xviii We borrow this term from Latour (2011).

xix Other research has also shown that roles and relations are becoming reconfigured in smart grid experiments and that this is not unidirectional (Katzeff and Wangel 2015; Throndsen and Ryghaug 2015).

xx Other research on smart grids similarly points out the difficulties in communication between experts, users and publics (Schick and Winthereik 2013).

xxi Such universals are no general transcendent ‚truths‘, but to borrow from Srnicek and Williams (2015, 78): ‘Universalism, on this account, is the product of politics, not a transcendent judge standing above the fray. […] The universal, then, is an empty placeholder that hegemonic particulars (specific demands, ideals and collectives) come to occupy.’

xxii See Foucault‘s relational and productive understanding of power sketched in Footnote 5.

xxiii Through this permanent experimentation of a former stable system the established governance structure is shaken and thus questions of a governance of trust in the system become explicit (Büscher and Sumpf 2015).