A traveler's guide to smart grids and the social sciences[1]

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Abstract

This paper serves as an introduction to a special issue on *smart grids and the social sciences*. There is currently a discourse of very high ambitions and anticipation regarding how the implementation of a broad collection of smart grid related technologies across scales and geographies would influence the performance of electricity grids, and through this play an essential role in energy transition processes, renewable energy implementation, de-carbonization etc. So far, the question of how to achieve the desired goals has largely been a technical endeavor. In this special issue, and in this paper, we explore some of the ways through which social scientists have begun to engage the smart grid development. Here, research mainly targets three distinct areas of scientific research. First, emerging infrastructures attract a large number of *imaginaries or visions*, which can be studied. Second, smart grids have explicit expectations towards its users inscribed in them. The second group of contributions gathered here traces these types of inscriptions and the various relationships that might emerge between new technologies and publics at different scales. Third, infrastructures are large socio-technical systems that have to be built. Studies of this kind of system building and transformation are collected in the third part of this issue.

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1. Introduction

Travelers still encounter different wall plugs in different countries. This pocket of resistance has survived decades of regulatory efforts to standardize the ubiquitous electrical grids that power everyday life in so-called industrialized countries. For once, this outdated collective noun – *industrialized countries* – is adequate. New types of factories first made use of the extraordinary flexibility that electricity provided, starting the journey towards the blanket coverage of today's grids. When bills such as the UK Electricity Supply Act (1926) and the US Public Utility Holding Act (1934) defined the construction of standardized nationwide grids, this was still a matter of providing the industry with easy access to power. Today, almost a century later, electricity grids span continents and reach billions of households. They are, however, still modeled after the basic principles laid out at the beginning of the 20th century.

If we believe the mainstream opinion amongst energy policy makers and technology developers, this is about to change. Existing grids, which in earlier times were an expression of a nation's development, are now suddenly labeled "dumb". The grids of the imminent future are considered "smart". This special issue deals with the broad range of technical, and above all, non-technical issues that are at play when one of the most indispensable infrastructures of industrialized countries is about to be replaced by a smarter version of itself.

When listening to its propagators, this smarter grid appears as a jack of many trades. While grids are primarily about energy transmission, smart grids are expected to change the relation between production and consumption. Smart grids are often presented as a set of tools to balance and optimize the electricity grid, and to mitigate climate change. Visions of this future smart toolbox tend to contain gadgets like smart electricity meters, new smart household appliances, in-home displays or other feedback technologies (e.g. mobile phone apps) combined with new types of home automation (e.g. Verbong, Beemsterboer, and Sengers 2013). In the smart energy future, householders might also combine the possibility of storing energy, with micro-production of electricity from e.g. wind or solar power. Through this combination electricity users are eventually expected to morph into "prosumers" (e.g. Katzeff and Wangel 2015, Haunstrup Christensen, Gram-Hanssen, and Friis 2013).

In energy transition processes such as the German "Energiwende" (the energy turnaround replacing nuclear through renewable energy), smart grids are expected to smooth out potential problems associated with intermittent wind and solar power. Moreover, proponents expect the new setups to raise user awareness about electricity consumption. In turn, this new awareness should result in altered practices of electricity consumption, more efficient markets, reduced workloads on electricity grids and a decreasing need to invest in new electricity production capacity. Thus, the smart grid is expected to take care of many problems, both social and technical. As Geert Verbong and colleagues recently noted: "*Proponents hail smart grids as a promise to solve almost every thinkable energy issue*" (Verbong, Beemsterboer, and Sengers 2013, p. 120). Smart grids consist of many components, actors and potential roles. In line with this, the answer to what it is, what it could become and what it should become will differ between implicated actors (Skjølsvold and Ryghaug 2015) that ultimately may agree only on one thing: that smart grids are "the future".

Much of this optimism is anchored in technical research and engineer-based calculations on technical potential, or economic calculations about something often labeled "user flexibility". Much of the practical work done to develop smart grids echoes this: such efforts are typically highly technology-centric. However, in recent years with the actual implementation of the first smart grid technologies in pilots, we have seen an increase in social-scientific research engaging in critical dialogue with this development.

Currently, smart grids are no longer a novel idea or concept. In several countries, industry and policymakers are in the process of rolling out technologies often associated with smart grids at various scales, from the transmission grid to households. This also entails much experimentation in demonstration sites. On an instrumental level, the social sciences evidently have a role in these roll-out activities, in understanding how households and other users perceive and handle these new technologies, and in formulating new strategies that might increase chances of technology uptake and success (see e.g. Rochlin 2014).

The contributions collected in this issue, including our introduction, includes the instrumental vision of social sciences as a vehicle to bring about technological success. But in many instances the ambition is more broadly to explore how social science, on its own terms and in collaboration with other disciplines, can contribute to the development and understanding of, as well as the critique of the smart grid. Thus, the questions asked by the contributors to this special issue are more varied than just "how can we make it work?". They ask what is, and what could the smart grid be in society? What aspirations do different actors hold for the technology? How can we understand the current development of smart grids? What happens in human-technology interaction across different scales as new gadgets are introduced? What consequences may different versions of the smart grid entail? Such questions, of course, do not exclude the instrumental search for successful implementation, as evident by many of the contributions in this issue, nor does it entail that an instrumental application of social science in itself is problematic. In this introductory article we explore how contemporary social scientists working or tapping into the many fields related to smart grids, work to produce different stories about humans and non-humans, about technology and society.

Infrastructures such as electrical grids share a specific attribute that makes them interesting for social scientific inquiry. However, this attribute also makes them a challenging topic: They are the invisible skeletons of societies, which means that they affect us in profound but mostly inconspicuous ways. The authors who have contributed to this special issue all handle this invisibility in one way or another. On a more basic level, the challenges of invisible infrastructures channel the field of study in this volume to pursue four distinct areas of scientific research.

First, energy technology transition processes, processes of innovation and policy production particularly when they touch critical infrastructure involve a multitude of actors. Since technologies can be interpreted differently by different social groups (Pinch and Bijker 1984), current actors produce different imaginaries, visions and expectations (e.g. Jasanoff and Kim 2009, Borup et al. 2006, Skjølsvold 2014).These representations of something invisible (because it does not yet exist, but also because of its future size and complexity) can be studied. Second, the technologies associated with smart grids are expected to inconspicuously support everyday life in the future. For this reason, they have certain expectations towards its users inscribed in them. The second and the third group of contributions gathered here trace these types of inscriptions. Firstly, there are studies that probe how individuals relate to, understand, and make decisions with respect to smart grid related technologies and energy use. Secondly, a group of papers take a more collective view on the use and consumption of electricity, studying social or political practices. Finally, infrastructures are large socio-technical systems that have to be built. Studies of this kind of system building and transformation are collected in the fourth part of this special issue.

Over the next sections, we will give an overview of these perspectives both in order to introduce the issue but also in order to say something about where this research field is moving: what new knowledge is gained, what are the potential blind spots and in what direction should we push social scientific research on smart grids further?

2. Social science themes in smart grid research

2.1 The study of imaginaries: technological systems, users and citizens

A specific challenge connected to the social study of infrastructures lie in their transparent (Shove 1997) and composite nature (Star 1999, p. 382). Travelers can easily fix the problem of having to use another electricity plug, because it affects only a tiny, visible, and easy to understand part of the grid. However, nobody has really seen the grid as a whole. We only have access to simplified representations of it. These do not account for the grids' actual complexity. The electricity grid, as every infrastructure, contains many layers that have been added through the course of history. As time passes, new elements are added to the existing infrastructure (Star 1999). Different electricity sources with very different characteristics are already combined in today's electricity grids. Smart grids will be built on top of existing infrastructures, and will add to the complexity and heterogeneity of the system. As this process unfolds, multiple actors are involved in formulating how the smart grid should end up looking, what it should do and how it should be understood. Thus, the smart grid is subject to interpretative flexibility (Pinch and Bijker 1984, Nyborg and Røpke 2011, Skjølsvold and Ryghaug 2015).

This flexibility, ambiguity or uncertainty is visible through studies in this issue that focus on imaginaries, imaginations, visions or futures where the smart grid plays a role. Such visions are important ingredients in shaping future infrastructures. They are essential for the formation of technology niches, which might eventually grow to alter technology regimes (Schot and Geels 2008, Kemp, Schot, and Hoogma 1998). They profoundly influence how actors communicate (e.g. Bakker, Van Lente, and Meeus 2011), and the way industrialists, scientists and other key actors position themselves and strategize with respect to publics (e.g. Barnett et al. 2012). Visions of the future also plays a key role in the development of policies (Skjølsvold 2014). Thus, studies of "the imagined" are studies of a particular type of knowledge object, and of the relationship between this object and its surroundings.

An example of such a study is Ingrid Ballo's exploration of "*the discourses of the techno-epistemic network in Norway*" (Ballo, this issue). Ballo describes how key actors and smart grid experts in Norwegian industry and governmental bodies envision a future smart grid, and in turn, how this vision influences their communication of the smart grid idea to lay audiences. The visions of the Norwegian techno-epistemic network, she finds, are very positive. They imagine a future where electricity users become more active consumers, where automation is widely implemented, where security of supply is increased and where new, intermittent renewables are handled smoothly. These futures are linked to prospects of actively engaged and economically motivated consumers. Thus, the lack of critique and focus on potential obstacles produces visions of a rather utopic character, which is hardly surprising in light of earlier related research in Norway and elsewhere (e.g. Strengers 2013, Throndsen 2013). The desire to achieve and produce this sublime future, Ballo argues, leads actors in the techno-epistemic network to communicate a glossy and sugarcoated version of the smart grid to lay people, a "stylized" vision where potential reservations regarding issues such as privacy, data handling, control and power are omitted (see Nyborg and Røpke 2013 for a related account). This, she argues, is problematic both in a democratic perspective, and in a more instrumental sense, because it is likely that the glossy version of the technology will serve to alienate users of the actual technology once it is implemented.

Aurélie Tricoire (this issue) conducts a similar exercise in her study of cooperation in the global and French smart grid industry. Tricoire first conducts a global network analysis, and shows that geographical, economic and historical peculiarities across geographies have produced scattered pockets of technological expertise. This prevents homogenized understandings of "what" the smart grid is, and what it might become in the future. Through the network analysis she illustrates that there are relatively few companies involved in the actual experimentation and technology development globally, which means that the potential heterogeneity of visions are not reflected well in the industry discourse. Instead, most actors take on a form of observer role, where they follow the technology development through quite passive project participation.

Tricoire finds the same pattern when she zooms in on France. Central actors are few, involved in many projects on multiple scales with multiple partners. The central actors tend to represent the traditional supply-oriented energy sectors, and they tend to promote a very distinct, energy oriented and supply side oriented view of what the smart grid could become. However, policy makers and technology developers often highlight how the smart grid will change the distribution of roles and power structures in the energy sector, thereby transforming the sector into something beyond what it is today. As an example, newcomers from the ICT industry are expected to fundamentally change the game. Tricoire shows that such actors have so far only been able to provide fuzzy and unclear visions of what future smart grids will look like, and that as a result, they are largely absent from the dominant smart grid discourse. This discrepancy between clear, energy oriented visions on the one hand, and fuzzy, unclear ideas anchored in other sectors and actors, is highlighted as a potential obstacle to collaboration between actors and new modes of innovation in this emerging field.

The role of imaginations, and what imaginaries do, is also central in the contribution of Franziska Engels and Anna Verena Münch (this issue). This paper is anchored in the German context, where a broad energy transition, the so-called Energiwende is central. The authors analyze the role and relevance of socio-technical imaginaries for the development of a smart micro grid at an urban innovation campus in Germany. Through this, it argues that while there are still many uncertainties with regards to both what will become of the Energiwende, and how the future smart grid will look, the development at this site has led to the establishment of a particular and commonly shared materialized imaginary. The campus serves as a niche, a protective space, and as a common vision of the smart grid, and consequently serves as a sort of "glue" which helps involved actors in producing a shared vision that helps them guide the innovation process.

These contributions all together illustrate that a focus on the imagined can increase our understanding of industry and policy dynamics. While the studies mentioned above focus on grand visions of the smart grid as a set of concepts or ideas, another set of studies zoom in to focus on a more particular, and perhaps more obviously "social" element of the smart grid, namely how users are imagined.

Earlier studies have highlighted that designers and implementers of smart grid solutions have an ambiguous relationship to users. On the one hand, there is a dominant technical and economic discourse where users are considered as an ideal typical *Resource Man (Strengers 2013)*, easily picking up on the new logic and gadgetry, and through this adjusting their electricity consumption patterns. This vision also implies a simplistic view of the social relations of this ideal user, who is typically a male without many obligations to family, children, pets etc. On the other hand, scholars have found smart grid experts to consider the smart grid too complex an issue for ordinary lay people to wrap their heads around (Schick and Winthereik 2013). This echoes a long social scientific tradition, where the imagination or configuration of users by technology developers and designers (e.g. Woolgar 1990), are studied through metaphors such as technological scripts (e.g. Akrich 1992).

The ambiguity when imagining the competence of prospective users is reflected in this issue. One example is Tomas Moe Skjølsvold and Carmel Lindkvist's analysis of the design practices in a smart micro grid project with users in Germany and Italy. They study a project that originally aspired to involve users in software development processes in order to ensure that users accepted the solutions. This goal rested on assumptions about users as active, techno-savvy and price sensitive. In other words the technology developers envisioned the users as a character who through active use of feedback technologies would change their electricity consumption. On the other hand, the same engineers were concerned. What if the future users did not have this competence? They asked themselves whether the users would really be of any help at all when designing the technology. Could the future users possibly understand the complexity of the technology? Eventually this doubt became so powerful that the engineers decided to dis-engage the users from the design sessions altogether. Instead of inviting real users on board, the project decided to make project engineers literally *act* as users.

Lea Schick (this volume) offers an account that provides critique relevant to the practice of smart grid developers and implementers, as well as a critique of dominant social science approaches. She combines document analysis and interviews with key stakeholders to study how users are imagined and the implications of such imaginaries. In the official Danish reports she studied, focus rests on how to "*activate flexibility*". She identifies two major strategies for this task. On the one hand, the reports point to a potential for new emerging aggregator markets, where new actors buy and sell the aggregated flexibility provided by e.g. electric vehicles or heating pumps. The other strategy is to produce services meant to engage people in their electricity consumption. Examples include apps and in-home displays. The reports, however, do not promote achieving flexibility through active user participation. Instead, there is a focus on making consumers invest in home-automation that will make life easier for all parties. In this way, the "flexible user" is configured or imagined as an *inflexible figure*, a comfort seeking and neoliberal consumer. As Schick points out, this is not so surprising, because it echoes much of the social scientific literature on smart grids and users to date.

Schick finds fuel for her critique against this view not primarily amongst fellow social scientists. Social scientists, she claims, have tended to anchor their critique in pre-defined concepts, for example from practice theory (Strengers 2012, Hargreaves 2011, Katzeff and Wangel 2015). Schick's account highlights that, while this has brought us much valuable insight, it might also obscure valuable critique formulated by engineers and smart grid experts. Schick urges social scientists to more actively take on board critique coming from within the empirical field, an *infra critique* (e.g. Verran 2014). Through interviews, Schick shows that actors in the field view users in a much more complex way than they are often given credit for, and that they indeed care about the display of social issues, identity creation and community building, through technology use and human-technology relationships. Smart grid expert both criticize the idea that users are strictly economically rational, and highlights the importance of smart grid related technologies for formulating and constructing concerns such as "being green". Here, Schick echoes Noortje Marres (2012) ideas about material participation and asks us to think about how matters of concern can be structured around material objects like the smart grid in new and productive ways.

2.2 Consumers, users, publics and citizens: human-technology relationships in smart grids

While the travelers' problem can easily be fixed by asking at the hotel reception for an adapter, disruptions in electricity grids have grave consequences for the affected societies (Nye 2010). This is because the grids are always linked with conventions of practice (Star 1999, 381). In the domain of electricity grids an example of this is what has been described as "social load", the causal connection between social factors - status, display, sociality, conventionality, security, convenience – with peak and base load patterns in electricity consumption (Wilhite and Lutzenhiser 1999). The interest in the relationship between energy infrastructures, and how such infrastructures are shaped by use reaches back to the 1980s. A small group of scholars challenged the idea that a model of strict economic rationality could explain energy behavior, and highlighted that an eye to the socio-cultural and psychological reveals a much more complex model of decision making, expanding what it means to be "rational" (Wilk and Wilhite 1985, Lutzenhiser 1988). Contemporary successors to these studies are often referring to theories of social practice (Shove, Pantzar, and Watson 2012) to understand the interplay between technology, culture, norms and the routines involved in shaping energy consumption. While traditional research on energy consumption has focused on end-users as "problem" or "barrier" (Oreszczyn 2004), contributions of this type aims to go beyond a simplistic antagonism between user and technology (Shove 1998, Janda, Trocchia, and Gwinner 2002, Aune 2007). While opening the black box of users has inspired a host of innovative research on traditional systems of energy provision, an approach that goes beyond images of stereotypical users is even more relevant for their smarter successors. Here, consumers are expected to take on a much more active role, and eventually morph into prosumers.

Many contributions in this special issue explore the relationship between new, smart grid technologies and their users: How are the technologies put to use? Why are they not used? What are their effects? How are smart grid devices understood by different users in different contexts? These contributions can be grouped in two groups of papers: A set of papers that addresses electricity consumption and use from an individualistic approach, and a group of papers addressing energy consumption as a more collective, societal endeavor.

2.2.1 The user as an individual

If the traveler does not by chance belong to the very small group of scholars of electricity grid standardization, the disruption of the wrong wall plug most likely will not result in more than a quickly forgotten note to self: next time bring an adapter. Other disruptions to the usual way of providing electricity that are introduced in households are expected to do much more than this. One example of such an intervention was studied by Franziska Bühler et al. (this issue). They are interested in the acceptance and understanding of so-called smart charging for electric vehicles. This type of smart charging could for instance allow for scheduling the charging of electric vehicles to avoid charging during peak hours. Thus, this paper shows how the smart grid as an infrastructure might be interwoven with other infrastructures, such as that for transport. This might again be an opportunity for aggregators in new markets, selling "flexibility". Through a study of users in a pilot technology trial, the paper assesses the attitudes and motivations of prospective users before and after the trial. The paper reports that those who tests the technology in this German field study reported positively on the technology both before and after the trial, and that they were indeed able to integrate this technology in their every-day life quite fruitfully.

Michael Fell et al. (this volume) also study user acceptance of technologies and solutions associated with the smart grid. In this case, the focus is on the combination of various tariffs with technologies for automated response to new price signals. Through a survey of British electricity bill payers, they take a particular interest in whether direct load control is acceptable for consumers. Here, electricity suppliers are allowed to cycle people's heating off and on for short periods in return for a lower flat rate cost of electricity. Earlier studies, the authors note, have found that such set-ups have been associated with perceived loss of control and autonomy on behalf of the consumers, and have therefore often been considered problematic. Contrary to such fears, the authors finds that "*the idea of direct load control is acceptable in principle to many (possibly the majority of) people, at least when operated within tightly defined bounds and with the option to override it*". Thus, the authors conclude, there is significant potential in automating the response to demand side signals over the coming years, and that innovation in this field should be encouraged.

These studies bring us back to two different approaches to the role of users in smart grids, illustrated also by several papers on smart grid imaginaries. On the one hand, Bühler et al. (this volume) prescribe an active role to users. In other words, for the smart grid to provide the expected results, electricity consumers should become much more actively engaged in the energy system. On the other hand, Fell (this issue) proposes a more technology oriented strategy, where such engagement and decision making is delegated to automated solutions. This echoes a long debate in social studies on energy, where theoretical camps have tended to argue over what is most important: Technology or behavior (Wilhite 2008)?

If consumers should take on a more active role, it is important to understand the dynamics behind energy consumption decisions. This special issue provides several ideas about how to consider this issue. One suggestion comes from et al. Malte Nachreiner et al. (this issue). Their starting point is a question of why the combination of smart meters and feedback technologies do not always produce the desired outcomes in terms of altered energy consumption behaviors. Inspired by psychological models of self-regulated behavior change, the authors break down the decision making processes related to energy consumption in four distinct phases: predecision, preaction, action and postaction. The authors go on to analyze which of these phases are supported by different existing smart meter information systems. Ideally, such system should support and provide information relevant for all stages, in order to assist in behavior transition processes. The authors find that the systems analyzed does much to raise awareness and to formulate what the potential problems with existing behavior might be (moving from predecision to preaction). However, the authors argue that while most people are interested changing their electricity consumption behaviors, the existing systems largely fail to support a move from a desire to change behavior (preaction) to actual behavior change (action).

2.2.2. Electricity use as a collective practice

So far, we have imagined the traveler as an individual. Eventually, these lone travelers return home to rest in the comfort of their familiar environment. Here, some travelers may reconvene with family or friends. This might entail joyful conversation and exchanges of friendly smiles, but also cooperation on daily tasks, household chores, as well as negotiations and potential quarrels over how to resolve frictions. One of the things the traveler would have to share upon returning home is the consumption of electricity. While some people live alone, many do not, and because of this, electricity consumption is to a large degree a collective endeavor.

In line with this, earlier research has explored the home as a site of electricity consumption, to illustrate the diversity of practices and understandings which influences outcomes within the household (Aune 2007). Thinking about households as homes, opens question about the dynamics of the home; who resides in these homes and how do their everyday life affect electricity consumption patterns, and the interaction with new technologies? Following such a line of inquiry, previous studies have focused on how feedback technologies have been domesticated. Many have discovered that feedback technologies might just as easily serve as catalysts for family conflicts, as they might lead to shifts in peak load patterns (e.g. Hargreaves, Nye, and Burgess 2010, Wallenborn, Orsini, and Vanhaverbeke 2011).

In this special issue, several papers zoom in on the household level to make sense of what is going on there in relation to smart grids. Inspired by theories of social practice, Sandra Bell et al (this issue), employs a model very different from the psychological model of self-regulated behavior change (Nachreiner et al., also this issue). The authors argue that energy use is shaped by five different core elements that together constitute social practices and their organization across space and time. These are conventions (e.g. social norms), capacities (e.g. technology design), rhythms, economies and structures (social and material). This constitutes the CCRES model of energy use. By employing this model, the authors analyze differences across gender and generations, to illustrate the complexity involved in ordinary household electricity consumption, as well as the potential difficulties involved in changing these practices.

The advantage of such an approach is that it serves to demonstrate the complicated features of electricity consumptions and conventions of social practice in households often obscured by the technical and economic discourse around "flexibility". Two other papers do more to make the picture even messier: Greta Barnicoat and Mike Danson (this issue) focuses on households where the residents are elderly. What happens when households consisting of older people in rural Scotland are equipped with smart meters, in-home displays and a wide range of sensors? The study shows that this group has problems both using and understanding much of the technology, which suggests that a more tailored and individualized approach to design might be in order.

Larissa Nicholls and Yolande Strengers (this issue) discus a different group, namely families with children, and the limitations faced by this group when it comes to "offering" peak-time flexibility. The paper discusses how families with children reason with respect to time of use (TOU) tariffs. These are often presented as an economic opportunity for households, where shifting the electricity consumption from peak hours is rewarded economically. While families with children tend to have the highest peak-time consumption, the authors show how practice flexibility is contained by the relation of the peak period to other periods of the weekday, along with its synchronization with school, work and childcare arrangements. Thus, they argue, TOU is unlikely to be very successful for this particular user group.

The findings of these three papers all together complicate the job for designers, developers and policy makers pushing the smart energy transition. Publics and users of smart energy technologies are an extremely heterogeneous group, and it is unlikely that they will all domesticate the involved technologies in the same way. This is further illustrated by Joeri Naus et al. (this issue), who studies the group of users that at a first glance might hold most promise when it comes to offering their flexibility and following the technological script. These are frontrunners or early adopters of technologies and solutions associated with the smart grid. Through a combination of quantitative and qualitative methods, their study focus on users who have some experience with energy management practices such as energy monitoring, renewable energy production or time shifting. Their study found that in general, users who had engaged in one of these practices were very eager to expand on their engagement and to get involved in new modes of cooperation, e.g. with neighbors. Further, they illustrate how related these practices are. However, the study also reveals highly ambiguous attitudes towards some typical smart grid elements. Particularly, demand control schemes led by traditional energy suppliers raised questions about autonomy and privacy. Based on their study the two authors find promise in pursuing a strategy of implementing de-centralized systems *"that enable the bundling of energy management practices"*.

The concern for privacy, ownership and storage of data is also a key issue in a study by Susen Döbelt et al. (this issue). Based on Austrian survey and interview data they investigate the potential privacy concerns of smart grid users. Who would consumers trust to store potentially sensitive energy data, and how can ICT-infrastructures be crafted to address such concerns? Based on the observation that Austrian consumers trust the energy utility, the paper provides several hands-on design recommendations for ICT architecture solutions.

We have now seen how electricity consumption with or without smart energy technologies are interwoven with other elements of social practice. This, however, is not necessarily limited to what goes on inside the household. Electricity consumption, and its potential changes through the implementation of smart energy technologies is also a political endeavor. Raquel Bertoldo et al. (this issue) provides an account elaborating on this from a French perspective. They explored the attitudes of representatives from French communities where smart meters had been installed. The authors discover that actual use and engagement with the implemented smart meter technologies had been marginal. Through focus group interviews, however, the authors find very strong political engagement. Inspired by social representation theory (e.g. Markova), the authors discovered that the groups tended to make sense of the technologies through mobilizing linguistic pairs of opposites: Discussions about collective vs. individual behaviors, private vs. public behaviors, and finally individualist vs. collectivist consumption models. The discussions lead the authors to conclude that smart meters are not only technological artifacts, but also “public policy tools” and “socially invested objects”. Thus, the authors combine a focus on social matters with an eye for material aspects of the smart grid. This leads them to conclude that there is a substantial untapped potential for facilitating material participation (Marres 2012) through smart meter design and implementation. In the study at hand, however, the smart meters main effect has not been to instigate practice changes. Rather, the authors argue, they have served as a potential enabler of social innovation and creative thinking about political change.

Similar conclusions are reached in the contribution of William Throndsen and Marianne Ryghaug (this issue), who gives an account based on focus group interviews with prospective users of smart meters, energy monitors and new electricity tariffs. The prospective users were recruited among participant in a Norwegian smart grid demonstration project. Through discussions with these prospective users, the authors discover that there is a distinct material political, or subpolitical potential in smart grid technologies, which currently is underexplored: Many users formulated active strategies against being scripted as pure homo economicus. In discussions about the prospects of offering flexibility to the grid, many of the users expressed that this would be out of the question if their only impulse to change came from price signals. Rather, many interviewees highlighted that they found this economic reductionism rather insulting. Surely, they argued, there were other reasons for them to alter practices beyond the household economics.

As an alternative, interviewees highlighted that if they were to provide such a thing as flexibility, they would have to feel that they contributed to the collective benefit of society, and to goals that were of a more communal character. For instance, they would be more than willing to contribute collectively if they believed that their actions could help society reach environmental or climatic targets, if they could help ensure national or local security of energy supply, or if they could ensure the security of other valuable goods. Thus, this paper also highlights the potential of constructing new and creative political concerns around technological artifacts associated with smart grids – an object oriented material participation (in line with Schick, this issue; and Marres, 2012).

3. Systems and transitions

In most parts of the industrialized world a non-matching plug while traveling is one of the main episodes where incompatibilities between different grid infrastructures remain visible. This is a consequence of the immense work that has been invested in building an all-encompassing electrical grid. These huge socio-technical systems that have evolved in the course of two centuries are now in the process of being remade in a way that will demand new system building efforts.

In this special issue system building is visible as an aspect in many of the papers we have already discussed, but there are also papers that look at this specifically. One way of addressing the systemic traits is by looking at individual system components. Sophie Nyborg and Inge Røpke (this issue) look at the role of one particular technology in the Danish energy system, namely heat pumps. The authors illustrate how the status and understanding of heat pumps in the Danish context has changed. Earlier, heat pumps were intimately framed, interpreted or ascribed meaning in relation to the fossil based electricity system. With the rise of the smart grid as an idea, its status as a failed innovation has shifted, because it has now come to be seen as an essential component in the future smart energy system, since it opens up for aggregating flexibility.

Another attempt at grasping systems transitions at a more general level comes from Hogne Lerøy Sataøen et al. (this issue) who compare the UK, Sweden and Norway. The authors are concerned with systems transitions and systems building at the level of national transmission grids. Mobilizing a combination of the multi-level perspective (MLP) and a focus on what they call politico-administrative regimes, they highlight that infrastructure transitions entail changes in technology, markets, regulations, politics, and society at large. The politico-administrative focus results in a particular view to the different structural, functional, and cultural features, such as political systems and norms for decision-making in the three countries.

Through a relatively detailed historical comparison between the three countries, we see, for instance how the Norwegian topography, population patterns across the country and political tradition have paved the way for a historically very decentralized grid development path, where local resources and locally embedded power plants play key roles. Combined with a present situation of nearly 100% renewable energy production through hydropower, this leads to the formulation of different arguments for developing and modernizing the grid in Norway than in the UK and Sweden. In Norway it is, for instance framed as a way to ensure security of energy supply, while in both Sweden and the UK there is a stronger focus on grid development as a means to fulfill climate policy. Thus, the system builders in Norway have largely had local concerns in mind. Across the border in Sweden, the Government and other national actors have been the key systems builders, aiming to develop a national central grid at a very early stage. The authors also illustrate how the three countries differ with respect to public participation and expert involvement when it comes to grid development.

What does the focus on politico-administrative regimes and grid development regimes provides in terms of lessons for future sustainable grid development? On a basic level, they provide the obvious answer that; “it is complicated”. More specifically, however, they stress the importance of creating inclusive participatory processes that give time for implicated actors to enroll and be enrolled, but that *also* allows for efficient decision making.

4. Concluding remarks

Will the smart electricity grid make the episode of the non-matching plug for the future traveler as incomprehensible as the phrase “to *dial* a telephone number” is for children today? This is of course an empirical question for the future. What we can say today is that the introduction of new tariffs, of new gadgets, of new technologies and communication systems will connect energy production, transmission and consumption in new ways and by doing so it will change all three aspects of today's energy regimes.

This opens the black box of existing energy infrastructures and sheds light on a variety of opportunities for improvements, but also potential problems. Many of these have been discussed in this paper and in this special issue, and we have reason to believe that the papers collected here represent the state of the art in the social scientific treatment of smart grids. However, there is still a room to push our understanding of the smart grid and what social changes it may bring about further. For instance, much has now been done to explore how smart grids and their users have been imagined. According to these studies, simplistic ideas about users and inevitable technological success seem to prevail, even though competing voices can be heard. How can the social scientific imagination challenge this status quo? What alternative imaginations and visions can be produced, and could they be anchored in more realistic social scientific insights about human-technology interactions?

We also saw that much social science has been conducted to test how in-home displays, new tariffs (e.g. TOU) and other gadgetry influences electricity consumption. When the technologies fail to produce desired outcomes, social scientists tend to turn to their theories in order to illustrate the gap between everyday practices and what technologies may offer or promise. If there is a mismatch, as there often is, this is usually criticized. Formulating criticism, pointing out technological/design flaws and unintended consequence are all honorable and important roles for social scientists engaged in understanding the construction, deployment and use of new technologies and infrastructures. However, one obvious question arising is how the social sciences also can play a more productive role in the years ahead. One promising route lies in trying to influence technology and infrastructure development in the direction of making everyday practices the basis of technology design exercises, and to write technology scripts anchored in the complex real life world of actual users, rather than in the image of a user that most likely do not exist (e.g. Jelsma 2006, 2003). When social scientists facilitate and accompany bottom-up or 'middle-out' (Janda, Killip, and Fawcett 2014) approaches to smart grid design, a clear alternative emerges to social science as just an add-on to achieve acceptance of technological solutions thought up by engineers. Thus, in our view grass-root initiatives and community based projects (Seyfang et al. 2014, Heiskanen et al. 2010) deserve more attention from social science than they have attracted so far.

Through approaches that starts with the needs and routines of users and communities rather than the schematic demands of more efficient systems (e.g. Goulden et al. 2014, Hargreaves, Nye, and Burgess 2010, Katzeff and Wangel 2015), designers and technology developers might be able to ask novel questions. For instance, how should one think about electricity? Is electricity best treated as a market commodity as any other commodity, or does it make more sense to talk about it as a collective good or a common pool resource (Wolsink 2012, Goldthau 2014)? Such questions become even more difficult as electricity systems become more polycentric and heterogeneous. Here, they become linked to global political issues, such as how to tackle climate change, while at the same time becoming linked to very intimate and personal issues. Who should know when you take a shower?

In the commercial sphere, the smart grid is currently a set of technologies bound together by massive efforts to produce new and innovative solutions. How should innovation be understood in the smart grid field, and how should it be pursued? What actor constellations should be promoted, and what are the dead ends? Should small, promising niches be protected and nurtured, and if so, how? When asking such open ended question a potential Pandora's box of new, complicated issues follow. How should we understand the power dynamics in the smart grid development? What is the relationship between public and private interests? What is, and what should the role of the public sector and legislators be?

As the Googles, Wikileaks and Apples of today and the future move into our fuse box, new questions will emerge that we have not yet considered. One thing seems clear, however, and this is that social scientists will have much work to do in the smart grid field in the years ahead. With this special issue, we hope to bring fuel to the fire, and to stimulate the social scientific imagination towards further efforts.

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