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A traveler's guide to smart grids and the social sciences☆

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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 For once, this outdated collective noun – industrialized countries – is adequate.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., [59]). 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. [28,21]).

In energy transition processes such as the German "Energiewende" (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

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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" [59], (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 [52] 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., [41]).

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 [40], current actors produce different imaginaries, visions and expectations (e.g. [25,10,50]). 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 [47] and composite nature [53], (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 [53]. 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 [53,35,52].

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 [45,29]. They profoundly influence how actors communicate (e.g., [4]), and the way industrialists, scientists and other key actors position themselves and strategize with respect to publics (e.g. [6]). Visions of the future also plays a key role in the development of policies [50]. 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) [5]. 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

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