Social Practices, Households, and Design in the Smart Grid

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Abstract Considerable effort is put into the design and development of cleaner and more efficient energy systems. In this paper, we describe the problems arising when these systems are designed from a top-down technological perspective and when much development fails to account for the complex processes involved since people and their practices are key parts of transitioning to new systems. The transition to a smart grid not only demands new technologies, but is also fundamentally dependent on households taking on a role as co-managers of the energy system. The chapter illustrates how the emerging research field of "sustainable interaction design" may play a role in supporting these roles and in shaping sustainable practices.

Keywords Smart grids · Energy use · Sustainable practices · Sustainable interaction design

1 Introduction

Most people do not even realize that they use electricity until the bill arrives. We just use things—we work and play on computers, switch on the lights, make coffee, and watch TV. Even though these things require electricity to work, it is not

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the electricity as such we think about, but the activities. Usually, we do not pay much attention to how our habits and practices rely on electricity use. This is something most people in industrialized countries may agree on. However, in many other areas of the world where the supply of electricity is not as reliable, people's everyday life looks different. For instance, in a country suffering from political and economic instability, the population is affected not least with regard to electricity supply. People may have long power cuts every day in their homes. When this happens, they are painfully reminded about having used electricity. The absence of electricity becomes the evidence for its existence. The lack of electricity is reflected in their lives in a way that radically contrasts their everyday practices from those in the Western world. The unpredictability of then electricity will be available affects households in that they have to learn which activities they need electricity for, and plan to do these when electricity is available. Thus, they might be forced to seize the opportunity to wash, iron, cook, and charge their computers when electricity is available, since they know that that might change from one moment to the next.

The above example describes a scenario where the energy system mediates practices in a way where the relationship between politics and people's household activities is very clear. The instability of the political situation leads to unsystematic delivery of electricity, which in turn has direct consequences for households' access to electricity. In Western society, the relationship evidently also exists, but here, the supply of electricity is taken for granted and conceived of as one of the cornerstones of a modern society. The energy system has traditionally been characterized by centralized production and distribution of electricity and clear institutional borders between the producers and users of energy. However, major changes are taking place in this system that forms the very core of modern society. New "smart" technology is directed toward making the energy system more efficient through peak load management, energy conservation, and local production of renewable energy. The term "smartness" denotes the integration of information and communication technology into the power system. Considerable effort is being invested into the design and development of cleaner and more efficient energy systems. However, these systems have often been designed from a top-down technological perspective, and much development thus fails to account for the complex processes involved since people and their practices are key parts of transitioning to new systems. Society faces a challenge in caring for technical, social, and psychological needs in the development and implementation of the future energy system. This challenge may and must be approached by combining competences from different fields. In this paper we highlight the approaches of social practices and interaction design.

The expected future of the electrical grid is usually referred to as a "smart grid." Although there is no unified concept of what a smart grid is, the transition to smart grids will involve the whole energy conversion chain from generation to consumers (SG3 Roadmap).[1] The power flow will change from being unidirectional to bidirectional between generation, transmission, and end users.

The transition to a smart grid not only demands new technologies, but is also fundamentally dependent on households taking on a new role in relation to the energy system. One aspect of this new role derives from the need for more active consumers who are encouraged to change their energy use patterns in response to supply conditions, e.g. through pricing mechanisms. The second aspect concerns households' involvement in the micro-production of energy, i.e. shifting from being consumers of energy to being prosumers. Prosumer is a term used to denote the dual role of a person being both a producer and a consumer of a certain commodity. Inherent to both of these aspects is the active participation of energy users as co-managers in the energy system.

Few smart grid visions and initiatives have, however, succeeded so far in recognizing and including the social side of energy use in a satisfactory way. Rather than embracing the socio-material complexity of energy use, end users are typically depicted as consumers/producers/prosumers driven only by environmental concern and/or potential economic benefits. Moreover, the willingness and possibilities of these end users to shoulder the role as prosumers and to adapt to the required changes in technologies and practices is rarely made a topic of discussion. Regardless whether ICT is considered as an option for dematerialization, demobilization, or smart operation, see, e.g., [1] end users are a fundamental cog in the wheel of energy production and consumption [2–4].

The aim of this paper is twofold. First, it aims at exploring how the vision of the smart grid fits with sociological insights on the constitution of everyday life and its energy use. Secondly, it discusses the role of interaction design for the formation of sustainable habits and everyday practices in relation to the smart grid.

2 Practicing the Smart Grid

2.1 From Technological Fixes and Behavioral Change…

How planners and policy-makers perceive citizens and behavioral change is decisive for the measures proposed and implemented [5–7]. In current sustainable development agendas, technological fixes and behavioral change often constitute the standard pair of solutions [4]. While technological development (i.e., energy efficiency) is left to market forces or promoted through supra-national or national standards, behaviors are typically tackled through economic incentives and educational campaigns to "empower citizens, as consumers, to make sustainable environmental choices" [26, p. 3]. This is because "only consumers who are aware

[1] IEC Smart Grid Standardization Road Map, June 2010, Edition 1.0.

of the benefits of energy efficiency and are empowered to make informed choices can be drivers for change" [27, p. 50]. Smart grid initiatives are no exception to this.

Indeed, it has repeatedly been shown that both information and incentives have an effect, but it is also clear that the extent of change is limited concerning the number of people influenced, the scope of the change, and the duration for which it persists (see e.g. [3, 4]). Such shortcomings are typically explained by a deficiency in knowledge, understanding, or commitment [8, 9]. This "deficit model" is typically based on the assumption that if people only knew better, they would change their attitude (A), their behavior (B), and the (consumer) choices (C) they make [10]. However, this "ABC model" of policy intervention receives little support in empirical studies on how information affects behavior [11–14]. One proposed alternative explanation is that many incentives and interventions have been too focused on making technical and economic sense while disregarding the social logic of energy use [4, 12, 15, 16]. This explanation is underpinned by numerous studies clearly showing that technical, social, cultural, and institutional dimensions also need to be taken into consideration in order to understand patterns of consumption [13, 14, 17, 18].

2.2 …to a Social Practice Approach

Warde [19], Shove and Pantzar [20], Hargreaves et al. [21], and Strengers [22], among others, have drawn attention to how practice theory may be used to understand transitions to sustainability. In contrast to the deficit-based explanatory models, social practice theory highlights that understanding energy use requires replacing the idea of individual consumers and instead focusing on practices (what people do) and communities of practice (in which socio-material environments those practices are played out). Accordingly, what people do, and why and when they do it, is not to be seen as the result of individual decision-making, but as both an outcome and a part of an intricate multi-dimensional ecology of everyday life practices, each sustained by a specific mix of materials, images, and skills [20]. The materials dimension comprises technologies and other matters needed to perform a practice. The images dimension comprises the meaning of performing a practice related to a desired image, and the skills dimension comprises both the knowledge and the know-how needed to manage a technology and perform a practice.

In the contemporary smart grid discourse, the materials are at the core; it is through the dissemination and connection of solar panels, smart meters, interfaces, and automation and control devices that the energy system is to become smart. But besides these ICT materialities, transition to a smart grid is also dependent on the dissemination of other types of consumer goods such as electric cars and smart washing machines, see, e.g. [23–25]. The proposed image related to the smart grid is that of the prosumer: an environmentally engaged and economically driven person with a benevolent view of technology; or, to use the wording of the

European Commission [26, 27]: an “empowered” and “informed” type of citizen-consumer. The smart grid also demands a certain set of skills from its users who need to be able to, first, select the “right” types of home appliances and other household technologies needed to make the smart grid function and, second, be able to use and control these technologies in the “right” way.

Drawing further on social practice theory, altering practices requires all three types of elements, i.e. materialities, images, and skills, to be taken into consideration, and not separately, but as a consistent whole: “new practices consist of new configurations of existing elements or of new elements in conjunction with those that already exist. From this point of view, innovations in practice are not simply determined by the generation of new products, images or skills. What really matters is the way in which constituent elements fit together” [20], p. 61.

Thus, in order for smart grid practices to emerge, the materialities need to be related to existing or created images with an appealing connotation, such as in Fig. 1 below, which portrays the smart home in an attractive way, but also to the set of skills needed to perform the practice. In some communities of practice these skills are already in place, in others they need to be developed.

From a social practice perspective, it becomes apparent that an introduction of smart grids does not only imply a change of technologies (from knobs and switches to interfaces, and from old appliances and machines to new and smart ones), but also of practices, which renders it crucial to take into account the entire socio-material context of the proposed change.

2.3 Smart Grid Practices

For the expected potentials of smart grid technologies to be realized, a number of prerequisites need to be fulfilled. Firstly, the smart grid entails a set of new technologies, competences, and meanings that need to be adopted by households. Secondly, the technology must not only be adopted initially, due to curiosity or a flair for novelties, but must be used continuously. In other words, it must become embedded into the practices of the households, which happens only when the technology is linked to both meaning and competence; “products (‘things’) alone have no value. They do so only when integrated into practice and allied to requisite forms of competence and meaning” [20]. If a smart meter is not meaningful to me, I will not use it.

The smart grid concept not only includes new technologies, but also entails a change in roles, namely adjusting energy use to the supply at critical times or in response to energy market prices, which might in turn involve a desired change in householders’ everyday practices in relation to optimal conditions for using electrical appliances. This is usually referred to as load balancing or load management and peak shaving. It might be controlled by the energy companies, or it might entail a change in consumers’ roles, depending upon which strategy is selected. As Nyborg and Røpke [28] observe, the smart grid concept is

Fig. 1 An example of an image of smart technology, also featuring materialities and skills. From: http://www.komsa.com.cn/en/product/product.asp?BigclassID=78

characterized by a high level of *interpretative flexibility* (see also [29]). This is a term from the social construction of technology research denoting how technological artifacts can have different interpretations for various social groups. The smart grid concept sometimes possesses conflicting interpretations of how technological solutions should be designed [28]. For instance, a major issue concerns load management in the household in order to provide flexibility. Should this be up to the households themselves or to the electricity companies? At least two major strategies seem to prevail. One strives for automatic design of dwellings and appliances, whereas the other is directed towards applying instruments to motivate householders to contribute to load balancing and peak shaving. The predominant instruments for motivating consumers to adjust their energy use are dynamic price models and visualization of energy use based on frequent measurements at the household level as well as the level of appliances. The latter will be treated in depth in Sect. 4.

In the following section, we will discuss how interaction design can be used as a tool to these ends, but first we will approach these challenges from a practice perspective.

Peak Load Management Through Laundry. Peak load management is a way to cut or shave peaks in energy use and/or to align them with peaks in energy production. Today, energy use in most households peak at the same time(s). The first peak occurs in the morning when people get up and get ready for school or work. The other, bigger peak occurs in the early evening when people get back home, cook dinner, watch TV etc. Proposals for cutting these peaks include shifting (some of) the energy demanding activities in time, for instance by having "smart" laundry machines take care of the laundry at night instead of in the evening—or during the day when the energy use is high in industries and other work places. However, such a shift relies not only on people being willing to change their laundry routines, but also on household having access to their own laundry machines, which is not always the case. Moreover, it is practically impossible to shift some practices (or the use of material components of practices) in time, such as lighting, cooking dinner, or watching TV. In these cases, the focus must be on energy efficiency rather than on peak load management.

Decreasing Energy Use Through Smart Metering. Another common proposal for smart technology (in the smart grid) to render the energy system more efficient and sustainable is the introduction of smart metering. Smart metering is a both automating and persuasive type of ICT through which the user can control and/or be informed about energy use at home. Much research has explored what effect smart meters actually have on energy use, and the results differ, from realized savings to an actual increase in energy use due to the increased possibility of controlling indoor climate, see e.g. [30, 31]. Clearly, economic or environmental gains do not always carry more weight than comfort.

3 Empirical Studies of New Types of Roles for Households

3.1 Changing Energy Use Patterns

In recent years, a few empirical studies have been carried out to analyze household behavior in a smart grid context. In [32], Christensen et al. explored how differences between Denmark, Norway, and Spain influence the understanding of the role of households in the smart grid. The study also points to challenges and discrepancies in existing approaches to integrating households in the smart grid. The authors especially emphasize the importance of understanding the interaction between smart grid technology and everyday practices.

Another study along a similar path is [33], where Nyborg and Røpke discuss lessons to be learned from smart grid experiments focusing on consumers and the role this type of experiments may play in the construction of smart grids. The experiment studied is the first relating to smart grids in Denmark. The potential of consumers' flexibility was the focus of the study. One question dealt with whether certain groups of consumers are more flexible than others. Another question discussed the nature of consumer groups that were *not* flexible.

The study identified five user profiles: the technical, the economical, the curious, the participating, and the comfortable. The first three are categorized as enthusiastic and the latter two as interested, signifying a lower degree of engagement. The profiles were segmented according to their use of the smart grid equipment installed in their home, their life values, professional background, knowledge of and relationship to "the electricity world," and their motivations for being part of the experiment [33].

The study also identified factors influencing user flexibility. These were: willingness, family composition, life situation, household infrastructure, and smart technology in the home. Some other interesting insights were that there was a significant flexibility potential in the use of heat pumps, that the householders displayed openness towards being controlled by an external stakeholder, and a relatively small experience of loss of comfort.

3.2 Micro-Production of Energy

The second change in practice concerns the shift inherent in the term "prosumers"—in the smart grid, the end users of energy will not only be consumers of energy, but also producers. Private production of solar power is already a reality [34, 35]. When end users become producers, this entails a change of the power landscape of energy provision, trading, and use. Thus, the smart grid implies a new wave of electrification [36] and new networks of power, in the very same dual sense of the meaning used by T.B. Hughes in his seminal book on the electrification of the Western society [37]. This change in the system boundaries of the energy system is positive, as it brings the previously black-boxed end use of energy out into the open, and in the bigger-picture types of energy systems analysis as well. In other words, the increasing interest in smart grids in policy and research holds the potential to make real a long-sought change in perspective on the energy system, from being seen and treated as a mainly technical system managing resources to a socio-technical system managing services [38].

4 Designing for Sustainable Practice

As observed above, materials are at the center of the current smart grid discourse. It is through the dissemination and connection of solar panels, smart meters, interfaces, and automation and control devices that the energy system is to realize its "smart" potential. Users, customers, and citizens emerge as vital links between the vision of the smart grid, technology, and new services. These are the end users of technology, and the way they use it depends on the context. Businesses as well as households may be users. The point is that people are carriers of practice, and their various skills in dealing with technology are part of a social practice.

We know from research in the behavioral sciences that the design of people's physical and technical space has a strong impact on their behavior. In the context of the smart grid, people must be regarded primarily in their roles as human beings, who are busy with their everyday activities and practices, rather than merely being users of electricity. The design of new technology relating to the smart grid needs to take this into consideration at every point of contact between people and the smart grid. It needs to take into account the users of the technology.

The design of this technology, including interface, information, etc., plays an important part in realizing the smart grid ideas in a way that also fits the users it is targeting.

4.1 Sustainable Interaction Design

The emerging research field referred to as "sustainable interaction design" [5] focuses on how interaction design may play an important role in shaping sustainable practices. So far, contributions in the field have mostly dealt with eco-feedback devices, i.e., devices providing feedback on certain types of energy-related behavior [39, 40]. The feedback usually consists of information on electricity consumption and conservation. Major research issues concern the relationship of the design of this feedback to comprehension, engagement, and behavior of users. Most studies target household practices [39, 41], but a few are also directed to workplace practices [41, 42]. Although applying design to engage people in the subject of sustainability is still in its infancy, some of the first experiments using interaction design for visualizing energy use were carried out around 2004—the Power-Aware Cord (Fig. 2) being an early prototype to illustrate how electricity feedback could be provided without detailed information represented in numbers or graphs [43]. The Power-Aware Cord is an ambient display in that its presence may be perceived with our peripheral senses, providing continuous information without being distracting or obtrusive. The Power-Aware Cord is a redesigned electrical power strip in which the cord is designed to visualize the energy rather than hiding it. When electricity is used, this is represented through glowing pulses, flow, and intensity of light. Expressing the presence of energy through light can inspire people to explore and reflect upon the energy consumption of electrical devices in their homes (Fig. 2).

Studies in human-computer interaction (HCI) focusing on the design of feedback to make users aware of environmental factors are sometimes referred to as studies of "eco-feedback." Froelich et al. [44] present a comparative survey of the literature in this area, which relates the framework of human-computer interaction to models within environmental psychology relevant for everyday life. The survey addresses behavior change and criticizes eco-feedback studies in that they do not attempt to measure behavior change. Some eco-feedback studies have designed games for teenagers as a platform [45] and studied the use and engagement of the rest of the household in energy conservation. Other examples of the design of domestic eco-feedback applications, which have been studied in households, include the Energy AWARE Clock (Fig. 3) [11] and EnergyCoach [41]. The clock is a portable energy display that can be hung on a wall, placed on a table, or carried around freely. It uses a time (i.e., analogue clock) metaphor to visualize electricity consumption in a home. One intention is to use the clock metaphor in order to depart from the concept of a meter and technological references to the discourse used in the domain of electricity. Another is to facilitate transfer of some desired

Fig. 2 The power-aware cord (designed by the Interactive Institute)

behavioral patterns, such as regularly glancing at an ordinary wall clock. The overall idea of the Energy AWARE Clock is to make electricity use more concrete in relation to ordinary activities as well as being a tool that could encourage discussions about electricity consumption in the home. Recent overviews of the field of sustainable HCI and interaction design are presented in [46–48].

4.2 Private Energy Production

User aspects of private and micro production of energy have recently attracted attention. Existing research literature on the user group is quite scarce. Only a few published studies around domestic solar power generation focus on the user groups per se [34]. Tengvard and Palm [34] interviewed 20 households and analyzed their decision-making regarding the adoption of small-scale photovoltaic panels and wind turbines. According to the analysis, environmental concerns are the main motive for these households. Some live ecological lifestyles in which the adoption of photovoltaic panels or wind turbines represents a way to take action in the field of energy. Yet for others the adoption is symbolic in displaying environmental consciousness. Finally, some are motivated by the opportunity to protest against the system with its large dominant actors.

The above results are supported by currently unpublished work from a study carried out by the Interactive Institute. It is important to note that the interviews reported above concern current private producers of wind and solar energy. However, research also needs to focus on the next generation of producers ("prosumers"). The motive of environmental concern identified by Tengvard and Palm [34] is also found in a consumer survey of 2,000 Dutch households [35].

Fig. 3 The energy AWARE clock (designed by the Interactive Institute)

Respondents were asked to report on their *intentions* to produce their own electricity. About 40 % of Dutch households have the intention to generate their own power, with an overrepresentation of young households. Results show that environmental concerns are the largest driver of households' intentions to generate their own electricity. Other motives were affinity to energy and to a lesser extent to technology. However, results did not point to financial motives for households to generate their own power.

Although some research has been carried out on the target group of private producers of energy, design aspects of the field are in their infancy. One issue to be addressed is how to enhance the experience of producing one's own electricity. Another is how to show users how their production relates to their consumption of electricity. This does not appear to be the main concern for manufacturers of solar panels. Some solutions for visualizing domestic energy production are available on the market. These are marketed by the manufactures of the inverters connected to the solar panels, and most of them target a technical user group.

5 Interaction Design for the Smart Grid

In the future electrical grid, people's consumption of electricity will have to be managed in response to supply conditions. This entails, for example, adjusting electricity use to supply at critical times or in response to market prices of energy. In turn, this will involve a change of everyday practices in relation to information communicated about optimal conditions for using electrical appliances.

To address issues oriented toward user aspects of the future electrical grid, research needs to focus on the role of design and design research in the transition to new behavioral patterns and social practices. We need to learn more about implications for people as users of the future energy system. Central issues concern how sustainable practices may be formed in relation to the future electrical grid, what kind of information is needed to attract and maintain people's attention, and how to provide engaging interaction models. Automation and intelligent technology play a role in the area of smart homes, but user aspects need more attention. However, some interesting research on the use of intelligent thermostats has recently been published [49].

Other important aspects are privacy, automaticity of household appliances and systems, and private production of energy. Research in design has a central role for developing concepts and prototypes for communicating relevant information with the purpose of engaging households in the changing energy systems. Questions need to be addressed concerning how design may integrate feedback, aesthetics, and playfulness to influence people's motivation and engagement to change their practices relating to electricity consumption.

In order for people to understand, trust, and make effective use of these new systems, careful attention must be paid not only to the more technical properties, but also to how their use is developed, introduced, and sustained over time. The transition to a smart grid and a sustainable society thus has to recognize the complexity of social practices.

6 The Social Practice Perspective Revisited

Although researchers of social practices use different types of theoretical frameworks, there is a consensus that a social practice perspective may open new opportunities to understand and potentially change everyday practices in a more sustainable direction [50]. This perspective implies that human activities are part of an ecology rather than isolated phenomena. They are viewed as parts of a system. This may facilitate the reformulation of the question "how can we change people's behavior?" into more fruitful formulations in terms of relations and dependencies such as those between everyday practices and power companies, producers of white goods, etc. Regarding electricity use and sustainable lifestyles from a social practice perspective facilitates the discovery of patterns in the analysis of empirical data. There is currently a lack of this type of empirical research. Hargreaves et al. [21] and Christensen et al. [51] provide exceptions.

Strengers [22, 52] approaches the Australian energy system from a practice-oriented standpoint according to which the power grid is seen as a technical system mediating social practices. Including material infrastructure as an element of everyday practices marks a clear contrast to the division between demand and supply characterizing the energy sector. Technology and human activity are clearly divided and approached by different disciplines. However, according to the social practice perspective, technology, infrastructure, and human action are all involved in constituting the practice. Instead of changing individual behavior, social practice theorists refer to a change of elements constituting the practice. This also entails a view of change as something emergent, dynamic, and uncontrollable [52]. The “problem” is about *transforming* technologically mediated social practices. Strengers [52] shows how social practice theory may refocus and reposition roles and practices of professions charged with the responsibility and agency for affecting and managing energy demand.

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