Association for Information Systems

AIS Electronic Library (AISeL)

ECIS 2023 Research Papers

ECIS 2023 Proceedings

5-26-2023

THE SMART METER AS A BOUNDARY OBJECT - INSIGHTS FROM AN EMPIRICAL CASE

Malin Granath

Johanna Sefyrin

Björn Johansson

Follow this and additional works at: https://aisel.aisnet.org/ecis2023_rp

This material is brought to you by the ECIS 2023 Proceedings at AIS Electronic Library (AISeL). It has been accepted for inclusion in ECIS 2023 Research Papers by an authorized administrator of AIS Electronic Library (AISeL). For more information, please contact elibrary@aisnet.org.

THE SMART METER AS A BOUNDARY OBJECT - INSIGHTS FROM AN EMPIRICAL CASE

Research Paper

Malin Granath, Linköping University, Linköping, Sweden, malin.granath@liu.se

Johanna Sefyrin, Linköping University, Linköping, Sweden, johanna.sefyrin@liu.se

Björn Johansson, Linköping University, Linköping, Sweden, bjorn.se.johansson@liu.se

Abstract

Smart meters are often understood as central devices in the smart, flexible and sustainable electric grid, enabling consumers to adapt their electricity use to current supply. In this study we are interested in how different actors in a Swedish context understand the smart meters and fit them into their locally situated practices and contexts, and we analyze the smart meters with the concept of boundary objects as an analytical lens with the purpose of describing and explaining tensions between actors in intended and actual use of smart meters. The case study builds on empirical material from policy documents, web pages and user forums, and include the Swedish government, authorities, grid operators and electricity suppliers as well as consumers. The main conclusions are that consumers were not included in the design and roll-out of the smart meters, resulting in that the available information requires consumers to be active and resourceful experts.

Keywords: smart meters, smart grid, boundary object, case study.

1 Introduction

In many western contexts the reliable availability of electricity is something that is taken for granted, however, recently we have become aware of its vulnerability (e.g., large power outages in Texas winter 2021, and shortage of gas in Europe during 2022, and as a consequence rising electric prices). Large outages not only instigate political discussions about the robustness of the electricity system, but also make the normally invisible and perhaps “boring” infrastructure visible and interesting (Star and Ruhleder, 1994, Star, 1989). Research reveals many challenges with the electricity grid, e.g., old technology, capacity problems, introduction of renewable and weather dependent sources (Ketter et al., 2018, Buhl and Weinhold, 2012). Recent developments of so-called smart grids could be seen as an answer to these challenges. The smart grid is often understood as a digital skin that is overlaid upon the conventional electricity grid; a skin that makes it possible to gather, process and analyze large amounts of data (Goel, 2015). In this sense the smart grid is also a digital infrastructure (Tilson et al., 2010). The smart meter, a central part of the smart grid, is a digital artefact which allows remote, two-way, (near) real time metering of energy consumption and communication between the grid operator and the meter and one-way communication between the meter and the consumer (near real time information about electricity consumption) (Wunderlich et al., 2019, Corbett, 2013). Smart meters are understood as a central in a flexible and more sustainable electric grids which include a larger number of and more differentiated actors (who are consumers as well as producers of electricity) and energy sources (Lazoroska et al., 2021). Lovell et al. (2017) underscore that smart meters are “typically combined with additional services and technologies such as in-home displays (IHDs) or phone apps – wireless technologies linked to the meter but not a core element of it” (see also (Buchanan et al., 2016). Here we are interested in exploring the different actors involved in the smart meters, including the intended users (consumers). Within the field of IS we have only found a few studies of smart meters which also include the consumers of the smart meter, making this a rather under-researched issue. These are for instance Warkentin et al. (2017), and Kranz et al. (2010) who focus on technology acceptance and privacy issues connected to the smart meter. Goel (2015) study anonymity versus security issues in relation to the smart grid, and (Corbett, 2013) explore whether smart grid information systems and technologies make a difference in utilities' efforts to promote energy efficiency, related to demand-side management. Johansson et al. (2022) address questions concerning how energy providers perceive the impact of smart meters on challenges related to demand-side management. There are studies focusing on consumers' adoption and use of smart meters, but they are conducted in other research fields (Lovell et al., 2017, Poderi et al., 2014, Hargreaves et al., 2010, Batalla-Bejerano et al., 2020, Adams et al., 2021).

There are several actors who have a stake in the smart meters, and who in different ways use it in their work practices including the Swedish government, authorities such as The Swedish Energy Markets Inspectorate, electricity traders, energy service companies, grid operators, producers of smart meters, (assembling) fitters, and the consumers of electricity, who in various ways do or do not use the meter as part of practices at home. In a press release in 2018 the Swedish government announced that it had decided to introduce new functional requirements for smart electricity meters in Sweden, and that the new meters should empower the consumers and stimulate the electricity market (Swedish Government, 2018). The task of developing these functionalities was given to the Swedish Energy Markets Inspectorate (Ei), with the aim to create equal conditions for consumers, grid operators, electricity producers and electricity traders, to enable a developed market for energy services, to fasten the process towards smart grids, and to align Swedish functional requirements with those developed by the European Union (The Swedish Energy Markets Inspectorate, 2015). The result was seven such functional requirements, developed in dialogue with a number of actors on the energy market, but not with the consumers. Among the mentioned actors there does not seem to be any consensus about the meter's meaning or intended or actual use. The meter seems to be rather open to different interpretations and use for different purposes, but at the same time it cannot be used for just any purpose. Nevertheless, despite the absence of consensus, the meter enables (and necessitates) collaborations between different actors. Because of this, we understand the smart meters as boundary objects, "objects which are plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (Star, 1989, Star and Griesemer, 1989, Star and Ruhleder, 1994). The concept of boundary objects was developed in order to explain the fact that in many contexts, actors with different professional belongings, aims, and practices collaborate in the absence of consensus – as Star and Griesemer (1989) explains , "[c]onsensus is not necessary for cooperation nor for the successful conduct of work". Lovell et al. (2017) discuss how the development and introduction of smart meters to householders is a process with unequal power relations and distribution of resources between the involved actors. In their study the consumers were less influential in the design of the meters, something which was a source of conflicts and difficulties during the roll-out phase.

In this study we are interested in how different actors understand the meters and fit them into their locally situated practices and contexts, and we analyse the smart meters with the concept of boundary objects as an analytical lens with the purpose of describing and explaining tensions between actors in intended and actual use of smart meters. The specific research question asked is: What do different actors expect from smart meters?

The rticle is organized as follows. In the section on previous research om smart meters, we present research on smart grid sand smart meters, including research done within the IS field. In the section on analytical framework, we discuss our use of boundary object as an analytical lens and boundary objects as part of infrastructures. After that we describe the methodology used in the paper, followed by the empirical background and material, together with an initial analysis of the material. We continue with a discussion on the results and finish with our conclusions and directions for future research.

2 Previous Research on Smart Meters

The background for smart grids is the increasing complexity and unpredictability of the electric grid. Electricity, in order to decrease climate change, is increasingly produced in more flexible and uncertain ways, for instance wind and solar energy, as well as hydro-electric power, in which weather and water supply decides the ability to produce electricity and thereby electricity supply (Shaner et al., 2018). Electric power stations fuelled by gas are insecure as the availability of gas might be hampered in for instance conflicts and wars (such as the current war between Russia and Ukraine) or sabotage (such as the sabotage of the gas connection in the Baltic Sea, Nordstream 1 and 2 during 2022). Nuclear power plants are sensitive for access to and temperature of cooling water (related for instance to a warmer climate) and tsunamis and must sometimes be shut off for maintenance (Kopytko and Perkins, 2011). Electric power stations driven by coal and oil are affected by the availability of these raw material, such as the oil crisis in the 1970s during which increased oil prices created an energy crisis (McGowan, 2011). This makes the production of electricity more variable and vulnerable, and necessitates that as the availability of electricity varies, so must the use, that is, consumers must adapt to variations in electricity supply (Corbett, 2013, Roth et al., 2021). Furthermore, the grid is becoming more decentralized, as “a larger variety of people own, manage, and benefit from energy infrastructure” (Lazoroska et al., 2021). As underscored by (Poderi et al., 2014) “[p]assive one-way communications and power flows centrally managed by large suppliers to consumers are giving way to a more (re)active and de-centralized paradigm” (Poderi et al., 2014). At the same time electrification is understood as the answer to many climate and environmental problems, and the increased use of electric devices and vehicles, as well as an electricity demanding industry, increases the demand for a reliable grid and affordable electricity prices. One way to solve this dilemma is to work with flexibility solutions intended to balance supply and demand of electricity in the electric grid (Adams et al., 2021, Batalla-Bejerano et al., 2020, Corbett, 2013, Hargreaves et al., 2010). This entails that the consumers of electricity are included and active. The involvement of consumers in the electric grid makes this a sociotechnical system rather than a technical system (Johansson et al., 2022), in which consumers, as users of smart meters are expected to, if they can, adapt their electricity consumption, based on information provided by for instance current consumption and prices (Hargreaves et al., 2010). In this way they could, potentially, decrease electricity consumption (demand) when supply and prices are high, and increase their electricity consumption when the supply and prices are lower. Within the current price model (based on supply and demand) this could even out the peak demand periods and lower the prices.

Extensive research has been carried out on the smart grid and the smart meter, mainly from a technical perspective. For instance, Avancini et al. (2019) argue that smart grids together with smart meters are part of what they call an intelligent energy network (IEN), with the purpose of making it easy to control power balance and demand-side management by integrating communication and control capabilities. Gungor et al. (2011) suggest that there are two types of infrastructure needed for the information flow in a smart grid system, firstly a flow of information from sensor and electrical appliances to smart meters, secondly, a flow of information from smart meters to the utility's data centers. When reading this body of rather technically oriented research the language used is full of terms such as optimization, control, feedback, balance and load, indicating that smart grids are understood mainly as technical systems rather than as sociotechnical systems. Wunderlich et al. (2019) study household adoption of smart metering technologies, but they seem to mean another kind of smart meter than those who are in focus in our study, namely meters which can be bought and plugged into specific electric devices and measure their electricity consumption, allowing consumers to identify electricity intensive devices in the home. These are combined with a smart box which communicates with the energy provider. Here it becomes clear that the concept of smart meter is used in several ways, indicating similar but not identical technical phenomena. Smart meter in this paper refers to those meters which measure the entire electricity consumption in a household, and which are necessary to have to enable the grid operator to access information about consumers’ electricity consumption. In Sweden the responsibility for installing these is laid on the grid operators. Lovell et al. (2017) conceptualize smart meters as boundary objects and study how these, in UK and Australia, are reconfigured by different actors, with a focus on the roles of households. They underscore how smart meters are understood as an agent of change, “a key ‘enabling technology’, allowing for greater engagement, interaction and influence on household energy practices” (Lovell et al., 2017), a technology which mediates the relations between utilities and their customers. These researchers furthermore point to the power relations involved in relation to the definition of the smart meters and ask, “Who defines the boundary object’s functions, and where and when it should be implemented and used, and by whom?”. They conclude that in their study, utilities and governments seemed to have more power in the situation than the householders, even though the householders in the study too showed ability to disrupt and obstruct the way utilities and governments had intended the smart meters to work. Such issues of power are central here. The introduction of smart meters into the electricity systems invite consumers to be more active, turn technical systems into sociotechnical systems, change the relations between the involved actors, and result in partly reconfigured power relations.

3 Analytical Framework

In this paper we will use the concept of boundary object as an analytical lens through which we study tensions and conflicts among actors in intended and actual use of smart meters. The concept of boundary object is used to signify an object, “something people (or, in computer science, other objects and programs) act toward and with. Its materiality derives from action, not from a sense of prefabricated stuff or ‘‘thing’’-ness. So, a theory may be a powerful object” (Star 2010). The term boundary implies that there are boundaries between these groups, and the boundary objects, through their flexibility and shared structure, constitute a shared space in which the groups can meet and cooperate. Boundary objects understood as “a set of work arrangements that are at once material and processual”(Star 2010), are vague, ill structured enough to keep an interpretive flexibility which allows different groups, or communities of practices, to adopt them for their own purposes. Thus they are vague as common objects, and open for locally situated groups to use them according to their specific interpretations and practices. Boundary objects enable groups to, without consensus, move between the vague and the specific interpretations of the object. Star (2010) observes that “a shared representation may be quite vague and at the same time quite useful”. Smart meters can be understood as boundary objects, things used differently by different groups, or communities of practices, such as the Swedish government, The Swedish Energy Markets Inspectorate, the grid operators, the electricity traders, (assembling) fitters, and the consumers of electricity. These actors all use smart meters in their own way, for their own specific purposes as part of situated organizational practices and aims, while at the same time the smart meters are also common objects (a shared space) which necessitates communication and cooperation between these groups.

Furthermore, when boundary objects become part of larger institutional practices, they change into infrastructures and standards. Star and Ruhleder (1994) point out nine characteristics of infrastructures; they are (1) embedded and as such often invisible and taken for granted, (2) transparent to use in the sense of not having to be reinvented each time, but provide invisible support, (3) they have a broad reach and scope, and reach beyond a single event or one-site practice, (4) they are learned as part of a membership of a community of practices, (5) they link with conventions of practice and are thus shaped by as well as shape the conventions of a community of practice, (6) they embody often conflicting conventions and gain transparency by plugging into other infrastructures and tools in a standardized fashion, (7) they are built on an already installed base and hence inherit strengths and limitations from that base, (8) they are usually invisible and become visible only upon breakdown, and (9) they are fixed in modular increments, not all at once or globally. This is relevant here since the electric grid and the availability of electricity indeed is an infrastructure which usually, at least by consumers, remain invisible and taken for granted, but it becomes highly visible on a breakdown. The meters are already standardized, at least in their physical shape, and in terms of functional requirements, albeit not in use. They are a part of the Swedish electricity infrastructure, enabled and restricted by governmental decision and policy making. However, the process of “rolling out” smart meters to Swedish households is still going on and have not yet become a part of stabilized practices on the part of the involved groups. As smart electricity meters are installed in households, these consumers are expected to become active parts of the electricity infrastructure and contribute to this through their changed electricity related practices, supposedly based on information provided by the smart meters. This would change the relations between the involved actors and make electricity a rather visible infrastructure, also for the consumers.

4 Research approach

This study is part of a larger research program called "Resistance and power – on smart grids for the many people", where researchers from different disciplines are working with different perspectives, methods and techniques to explore and analyse new actors, the role of the households and design in and of the smart grids (cf. https://smartgridsforthemany.se). This particular study contributes to design perspectives and the role of different actors in the smart grid and the study was conducted as a qualitative case study (Walsham, 2006). The analysis is based on a smart meter case in Sweden, and the case is interesting for at least two reasons; one is that Sweden is in the middle of a roll-out of a new generation of smart meters with the capacity to report electricity consumption every 15 minutes, and second the electricity prices have become much higher than most Swedes (and Europeans) are used to, something which might change how actors understand and use the smart meters. For this paper – the smart meter as a boundary object – we have primarily used secondary data in form of policy documents, web pages about smart meters. In the data collection it has been important to capture how different actors (e.g., authorities, utilities, consumers) suggest/expect/intend to use as well as how they use (or not use) the smart meter. In the reporting of our material we have chosen to categorize the results into three different types of practices: (1) policy-driven smart meter practices, (2) utility-driven smart meter practices, and (3) user-driven smart meter practices. Table 1 shows material used for the purpose of this paper.

Type of practice/actors	Characteristics	Role in relation to the smart meter
Policy-driven practices		
Swedish government	Executive authority in Sweden	Deciding body of the roll of out the second generation of smart meters in Sweden
The Swedish Energy Market Inspectorate (Ei)	Regulating authority commissioned to strive for well-functioning energy markets	Responsible authority for investigation and proposition of new functional requirements on the smart meter
Swedenergy	Non-profit industry and special interest organisation for companies that supply, distribute, sell, and store energy	Responsible for development of technical standards guiding the grid operators in their choices of smart meters (controlling regulative requirements of the smart meter)
Utility-driven practices		
Ellevio	Grid operator	Grid operators are the formal owner of the smart meters and responsible for collecting metering data Electricity trading companies use smart meter data to bill customers
E.ON	Grid operator/electricity trading company	
Göteborg energi	Grid operator/electricity trading company	
Mälarenergi	Grid operator/electricity trading company	
Tekniska verken Nät	Grid operator	
Vattenfall	Grid operator/electricity trading company	
User-driven practices		
Electricty-related user forum	Social media group	Forum where electricity consumers discuss electricity issues in general (including the smart meter)
"Smart meter" user forum	Social media group	Forum where electricity consumers discuss their usage of specific home energy management systems

Table 1 Overview of empirical data (type of practice and actor and their role in relation to the smart meter

Policy-driven practices represent actors that we have found to have impact on the design and implementation of the smart meters, i.e. by setting up regulations and requirements concerning the design of the smart meters. Empirical data has been gathered through accessing involved authorities web pages in combination with access to public documents on design and technical requirements concerning the smart meter. *Utility-driven practices* cover the energy companies' perspectives of the smart meter and their usage. Empirical data used to illustrate this perspective comes from electricity grid operators' and energy suppliers' public information about the smart meter. The grid operators are the formal owners of the smart meters and the smart grid, and in Sweden grid operators have monopoly on this technical infrastructure. This means that the customers cannot choose who they want as an operator, nor can they influence the choice of device. The supply side – the energy providers – on the other hand, is market based and thus open for the customer to choose. Empirical data has been gathered through accessing energy companies' (grid operators and energy providers) web pages and documenting how they have motivated and described both the change of the smart meter and descriptions of intended and expected use of the new meter. *User-driven practices* are in this paper represented by electricity customers taking part in different social media platforms/forums where electricity and smart meter technologies are discussed. To capture this perspective, we have joined two specific user forums on a social media platform (anonymized in this paper) and observed how different discussions have unfolded in these forums. Using social media could be questioned from an ethical perspective given that consent has not been given, however, our interest has not been on the individual, but on their use of the smart meter. Further, to address ethical challenges, we have chosen to not only anonymize the participants in the forums, but also the forums and platforms as such. The two forums we have chosen to use in this analysis we have chosen to frame as "electricity-related user forum" (with approximately 544 users) and "smart meter user forum" (with approximately 11,6 thousand users). We understand the first group as a mixed group of people with general questions and interests in electricity meanwhile the other group is group of people with special interests and knowledges above the average consumer in the area. The participants in "smart meter user forum" generally appear to have packages of smart energy solutions in their homes, e.g., solar panels, electric vehicle(s), and smart home automation systems for regulating temperature. Even though this group includes a larger number of users, it probably still represents a smaller percentage of energy users in Sweden.

The point of departure or the data analysis has been the smart meters, and how different actors understand these and fit them into their locally situated practices and contexts, and we analyse the smart meters with the concept of boundary objects as an analytical lens with the aim to explore tensions and conflicts among actors in intended, expected, or suggested use and actual use of smart meters. The use of boundary object as an analytical lens is rather frequent in IS research (Bergman et al., 2007, Doolin and McLeod, 2012, Forgues et al., 2009, Gal et al., 2008, Ghazawneh and Henfridsson, 2013), but we only found one study with a focus on smart meters (Lovell et al., 2017). The boundary object concept was used in the analysis in order to make visible how different actors – even though they all used the same digital artefact, the smart meter – seemed to interpret and relate to smart meters in different ways, hence incorporating the smart meters in quite different and sometimes conflicting organizational or household practices.

Due to the limited amount of space in the paper we have focused on three different practices, each including different actors, (1) policy-driven smart meter practices, (2) utility-driven smart meter practices, and (3) user-driven smart meter practices.

5 Empirical Background and Findings

The smart meters, in a Swedish context, are devices that measure the electricity consumption in a household or a building and shows how much electricity that has been used in the household or building since a specific start time. Lovell et al. (2017) write that smart meters are "typically combined with additional services and technologies such as in-home displays (IHDs) or phone apps – wireless technologies linked to the meter but not a core element of it", but this is not the case in Sweden. The smart meters are owned by the grid operators and are part of the electricity infrastructure. The grid operators are working on a monopoly market; even though there are quite a few grid operators, there is only one grid operator working in a specific geographical area. The companies which produce, distribute and trade electricity on the other hand are exposed to competition since the 1990s. The smart meters do not show how much electricity that is currently used by a specific device in the house, or how much electricity that is currently used by the entire household. They also do not show how much the electricity price is. The smart with the smart meter seems to be that they send information about electricity consumption wireless, that is, it is not necessary for someone from the grid operator to visit the meters and read them in order for the grid operator to find out how much electricity a specific household has been using since the last reading. Previously, before the existence of smart meters, this was done once a year.

The "new" smart meters (see picture 1) which are currently being rolled out send information about electricity consumption to the grid operator every 15 minutes. The grid operators use this information in order to bill the consumers for the amount of electricity that is transferred through the grid (a grid service fee based on amount of transferred electricity) and communicates the information to the electricity traders who bill the consumers for the electricity they have used. These new smart meters are also equipped with a specific HAN (Home Area Network) port, which can be used by consumers to plug in a device which enables them to see the information almost in real time. The meter is hence part of several practices, e.g., policy making practices (regulations concerning new functional requirements), grid operator practices (involving the formal owners of the smart meters), and electricity supplier practices. The smart meter is often delivered by a third party supplier (through a B2B solution), offering a package solution including installation, operations management, and service and maintenance, and thus constitutes an important practice in itself. There are also consumer practices, involving different kinds of consumer who do, or do not, use the smart meters in various ways, as part of their practices at home.

Picture 1. Example of a smart meter (photograph by one of the authors).

Sweden has a history of low energy prices and a stable supply of electricity due to electricity production mainly through hydro-electric and nuclear power. Most consumers have been uninterested in decreasing their electricity consumption since the prices have been so low that the profit would be only marginal. Thus electricity has indeed been an infrastructure invisible for most consumers, expected to simply work (Star and Ruhleder, 1994). However, during 2022 the electricity prices increased due to increased gas prices in Europe (Sweden's electric grid is connected to the European and fluctuations in the European prices affect Swedish electricity prices too). There has been a lot of attention to this from the Swedish politicians and mass media, as well as EU, and many consumers have now adapted to higher electricity prices. Svenska Kraftnät, the Swedish authority responsible for the maintenance and development of the Swedish electric grid, reported that in September 2022, Swedish consumers decreased their electricity consumption with 18% (see: https://www.svk.se/press-och-nyheter/press/hushallen-kapar-elforbrukningen-kraftigt-i-september---3333082/). This decrease was probably not enabled by the smart meters though, since they do not show actual electricity use, but rather by information available from other information sources, showing the spot prices on the Nordic electricity market, which sets the prices for Swedish electricity traders (such as such as www.elbruk.se or mobile apps). So, from this description of the smart meter and its development it is interesting to explore the practices of smart meters.

5.1 Smart Meter Practices

Below we provide examples from the different practices; (1) policy-driven smart meter practices, (2) utility-driven smart meter practices, and (3) user-driven smart meter practices, and how actors within these different practices communicate about how they view and make use of the smart meters. By doing this we also note what they do not do.

5.1.1 Illustrations of outcomes of Policy-Driven Smart Meter Practices

The initiative of implementing a second generation of smart meters in Sweden was made in order to fulfil EU regulations. The main arguments put forward by the Swedish government for implementing a second generation of smart meters was to strengthening the position of the consumer and at the same time guarantee robustness and efficiency in the maintenance of the grid. In a national press release the new smart meter was described as an object that would "empower consumers and stimulate the electricity market" (regeringen.se, published 2018). In the press release the customers were underscored as central. Consequently, in 2018 new functional requirements connected to the electricity meter were decided by the Swedish government with the motive to make the meter smarter. These requirements were developed and proposed by the Swedish Energy Markets Inspectorate (a regulating authority). The resulting seven functional requirements, developed in dialogue with several actors on the energy market, but not with the consumers, illustrate a technical perspective on the smart meter (Funktionskrav-på-elmätare-Författningsförslag-Ei-R2017-08, www.ei.se, 2022). Six out of the seven requirements focus on technical descriptions of measurement of voltage and registration of in and out data, and different remote functionalities (e.g., on/off switch, measuring and reading of data). Based on these requirements the consumers no longer seem to be so central. There is only one requirement that focuses on the consumers and the consumer interface and is formulated as follows:

> *The meter should be equipped with a customer interface, supported by an open standard, for the customer to be able to take part of the measured values (see functionality no. 1) in near real time. (Funktionskrav-på-elmätare-Författningsförslag-Ei-R2017-08, www.ei.se, 2022)*

This particular requirement also provides information of what the smart meter is not to be used for "It should not be possible to send information to the meter through the interface." (www.ei.se). Thus, the meter is not to be used for two-way communication between the customer and the grid operators. The requirement also stipulates what is required of the customer to get access to the interface and thus also the information.

> *The interface needs to be activated by the grid operator, on request by the customer, to provide information. The grid operator should control the identity of the user and must deactivate the interface when the customer moves out. (www.ei.se)*

This statement indicates that customers, in order to be able to get access to information, must be informed and rather active. Based on this requirement from the Swedish Energy Markets Inspectorate – concerning the customer interface – Swedenergy (interest organisation working for the energy companies in Sweden) has proposed a technical standard (recommendation) for the customer interface. The recommendation is that the customer interface should be physical in character and build on international standards. Arguments put forward by the energy companies are that a physical (tangible) interface, such as the meter itself, 1) marks responsibility boundaries in a clear way, 2) is more secure when it comes to cyberattacks, 3) makes it easier to standardize, and 4) is designed for a long term use (Industry recommendations on local customer interface for electricity meters, Swedenergy, 2019, p. 3). This indicates that the requirements are developed from a technical perspective rather than from a consumer perspective, and that the grid operators' interests are primary. Further, it is stated that the recommendation only describes "the physical interface and data transferred to the customer, not how data is used", and it is pointed out that:

> *[t]he grid operators are responsible for the electricity meter and its local customer interface, and data that is being transferred through the interface. (Industry recommendations on local customer interface for electricity meters, Swedenergy, 2019, p. 8)*

This concerns the relations between the grid operators and the consumers in terms of who is responsible for the technical device and the data it enables (the grid operator). And in the same way as the Swedish Energy Markets Inspectorate argued for in their requirements, the recommendation put forward by the energy companies also state what is not part of their practice:

> *The grid operators do not take responsibility for the external equipment that are connected to the interface nor any consequences of the customer's use of data. (ibid).*

This statement concerns the limit to the grid operators' responsibility; they do not take responsibility for any consequences of consumers' use of the data. They also specify what kind of data that is being transferred to the customer and how they look upon this type of data – for which they also do not take responsibility:

> *The data sent out via the interface is of the nature of statistics and thus not to be considered as billing values, since this data has not undergone the quality checks that take place in the electricity network company's collection and billing system." (ibid.)*

While the customers were identified as central by the government, the energy market actors placed their own interest as central and the consumers only second. The language used in the above statements is very technical and possible to understand only for those who have expertise knowledge about these things. These policy practices seem to be driven mainly by actors belonging to the energy sector itself – involved authorities and grid operators – and the examples above indicate that they see the meter as an object marking a boundary between their responsibility for the technical infrastructure and the customers' responsibility for its (unintended) use. The importance of this distribution of responsibilities is also something that our interviews have confirmed.

5.1.2 Illustrations of Utility-driven Smart Meter Practices

As pointed out above, the roll out of new smart meters in Sweden is based on new directives from the government for more precise metering and this is also something that the energy companies acknowledge. In line with the political rhetoric, energy companies also argue that the change will lead to safer, smarter and more robust distribution, but also to smarter homes and better environment (e.g. Gothenburg energi, 2022, E.ON, 2022, Ellevio, 2022). The meter is described as an important condition in the transition to a more flexible distribution and consumption and something that paves the way for a new electricity market. Below are two different examples of how energy companies communicate their views about the role of the smart meters in relation to the increased demand and use of renewable energy sources.

> *With the new, smart electricity meters comes new features and detailed information that allow us to bring more wind and solar into our electricity grids and develop them to be more flexible and efficient. (Ellevio, 2022)*
>
> *Our – and your – new smart meter, […] will increase the amount of meter data and the number of parameters that we measure in addition to your electricity consumption. [The smart meter] is well prepared for measuring production, which is necessary if, for example, you are installing solar cells. (Göteborg energi, 2022)*

Energy companies appear to be more inclined to make use of the technical requirements which has to do with access to more frequent and granular data on measurement of voltage, current, active and reactive power (Functionality no 1, 4 and 5, in Funktionskrav-på-elmätare-Författningsförslag-Ei-R2017-08, www.ei.se, 2022). The language, however, seems to require expert knowledge:

> *We will also measure the voltage in the grid, which gives us the conditions to become more proactive and fix errors before they affect you as a customer. (Göteborg energi, 2022)*

> *Through new technology and a better understanding of society's energy needs, we can also adapt the networks and avoid bottlenecks in the grid. This also makes it easier and faster to predict, prevent and shorten power outages. (Ellevio, 2022)*

In some cases, the grid operators also explain the technology behind the communication of data, e.g.

> *The meter contains components for recording consumption, voltage quality and possible power outages, but also a built-in terminal that stores the meter data and handles communication with other meters and/or with the central system on Mälarenergi's servers. The terminal is thus the component that sends and receives data. (Mälarenergi, 2022)*

From a utility perspective it is seems as though the new smart meters are a condition for the customer to plug in new smart home functionalities. It is also clear that this demands both additional equipment and additional actions on behalf of the consumers (demanding activation of the HAN port), something which, again, indicates that the customers are expected to possess resources in terms of expert knowledge and time. The example below illustrates that the grid operator hands over this responsibility on the customer.

> *The new meter also has direct benefits for you as a customer. It is a prerequisite for both smarter electricity grids and smarter homes. By switching on services, you get a clearer picture of your electricity use, can compare consumption with that of others and get the opportunity to influence it. (Ellevio, 2021)*

The information about the HAN port is generally technical in character, e.g., explaining what technical standards that are used. The electricity companies also explain what type of data consumers can access through this port, like in the following example:

> *Parameters that you can extract through the HAN port are:The current date and time of the meter, Metering id, Metering type, Instantaneous effect in all four quadrants (import, export, active, reactive), Total energy (mileage) in all four quadrants (import, export, active, reactive), Voltage per phase, Current per phase, The data stream is pushed out of the meter every 15 seconds. (Mälarenergi, 2022)*

The same information can also be accessed in the meter itself and grid operators use web-based manuals, often in the form of frequently asked questions, to show how user can access different data in their meter. Thus, consumers must actively seek this information in order to find out how to use the meters. However, it is also clear that it demands additional actions if the customer wants to know his or her consumption during a specific period of time, like for example the consumption during the last 24 hours, the last week, the last month. The quote below illustrates that the customer must calculate his or her consumption manually (!).

> *The display at the top of the meter shows your mileage, i.e. purchased electricity, in kilowatt hours (kWh). [...] To find out how much electricity you used in a given period, compare the meter reading from the first to the last day of the period you are interested in. The difference between these values shows your electricity consumption. (Tekniska verken, 2022)*

These statements suggest that the companies view the smart meters as technical devices, which help them to access more granular data concerning the wellbeing of the grid and more accurate billing information. Again, the consumer perspective seems to come second, and the consumers must instead have expert knowledge in order to be able to understand and use this rather complicated and technical information.

5.1.3 Illustrations of User-Driven Smart Meter Practices

Earlier in the paper we discussed that electricity recently has become an issue also for Swedes especially due to high electricity prices. The has led to an increasing demand of information and especially information about real time costs on electricity usage. One could thus expect that this also would lead to higher interest in the smart meter and its data on usage. Illustrations below are based on material from two different social media forums, which we have chosen to call *"smart meter" user forum* and *electricity-related user forum*.

Discussions in *"smart meter" user forum* mainly revolves around helping each other install and understand how to connect home devices to the smart meter, educating each other on the different devices and helping each other interpret information given by the devices. When it comes to more specific issues regarding the smart meters itself it is often questions regarding when the grid operator can be expected to install the new meter and how to get access to the HAN port. However, we have also noted general frustrations connected to the limited user interface of the meter itself. The post below is an excerpt of a post and illustrates an example that generated a discussion on the local interface. The discussion shows how different users interprets the roll out, and how they help and educate each other on how to use the smart meter (i.e. interpret the interface). The conversation also reveals that the information given by the smart meters is not new in itself.

> *Post: One thing I've been thinking about is that how is it possible that people in Sweden spend billions on switching to smart electricity meters and that these by default do not have an easy way to see consumption in real time without having to buy additional hardware? Surely that should be the first thing these meters should measure and visualize if there is any kind of feeling for the customer and willingness to help lower electricity consumption? (participant in "smart meter" user forum, October 7, 2022)*
>
> *Response: I'm guessing it's because the utilities in no way want to deliver the kind of consumer services that require further development and support. However, there is nothing to stop them from doing so, but then on the same terms and interface as the rest of the market.*
>
> *Response: On mine, you can see the consumption in real time in watts with a couple of button presses. Doesn't that work?*
>
> *Response: You can see instantaneous consumption on virtually all meters today. But data is sent much less frequently.*

In the *electricity-related user forum* we have also encountered examples of how people design, develop and share mobile apps of their own. One example of this is a user who was tired of all the nudging to convert to the energy companies' own solutions, stating that "all I really want is to know what the electricity costs" (participant in electricity-related user-forum October 24, 2022) and as he put it:

> *The purpose of the app is to: 1) Give me an idea of what the electricity costs right now in my electricity area, 2) Help me know when to consume electricity to keep the cost down and contribute to a more sustainable energy use*

Data feeding the app with necessary information in this case is gathered from an open API (called Entso-E) and not the smart meter. This also means that the user of the app does not get information about his or her own energy consumption, but general information about the price situation in their electricity area. This example could be interpreted as a workaround of the smart meter, and at the same time it illustrates what type of information customer are in need of. Prices in combination with individual electricity consumption appears to be important to consumers in these forums and often the consumers call for an app to see and follow up on their individual use. In both forums, it is clear that some energy suppliers provide this type of service, but at the same time, discussions show that customers prioritize easy access to solutions, and that they are not necessarily loyal to their chosen supplier.

> *If you do not have Tibber or Greenely. How can you follow your consumption and cost if you have an hourly rate, like you can so easily do at the mentioned companies? (participant in electricity-related user forum September 1, 2022)*

> *Best app to keep track of current hourly rates of electricity? (participant in electricity-related user forum November 10, 2022)*

In sum, these users appear to have little interest in the smart meter itself and those who have an interest in the meter are mainly interested in how to make optimal use of an assemblage of devices to be able to follow up and plan their individual electricity usage. Most users in these forums appear to prefer apps that can help them reduce their consumption and get control over their electricity bill.

6 Discussion

The treatment of the smart meters as boundary objects (Star 2010, Star and Griesemer, 1989), "objects which are plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (Star and Griesemer, 1989) makes visible that the different involved actors understand and use the smart meters in quite different ways. Here we focused on the government, the Swedish Energy Markets Inspectorate, the grid operators, electricity suppliers and different consumer groups. These all use the smart meter as part of different practices and for different purposes, without consensus (Star 2010, Star and Griesemer, 1989). Still the smart meters drive cooperation between actors, such as between the government and the Swedish Energy Markets Inspectorate, which cooperated with grid operators and electricity suppliers in order to develop the seven functional requirements, and the grid operators are responsible for installing the smart meters in the households.

The government underscored the smart meters as objects which would empower consumers and stimulate the energy market. This was the government's local interpretation of the smart meters (Star 2010). When the responsibility for developing functional requirements for the smart meters were handed over to the Swedish Energy Markets Inspectorate, this was done in cooperation with market actors but not with the consumers, and the result was seven requirements with a strong emphasis on technical issues. Of the seven requirements only one was addressing the consumers, and the others addressed the market actors' more technical interests in the meters. Some of the policy texts we found indicate boundaries between responsibilities for the technical grid and the consumers' practices, suggesting that the market actors are interested in keeping the customers out of their practices. The statements we found speak in a technical language, indicating a view of the electric grid as a technical rather than a sociotechnical system. This was another local interpretation of the smart meters (Star 2010). This technical language is possible to decipher by those who are already working with these issues, and by informed and expert consumers. In order to fully understand and use the functionalities provided by the smart meters, consumers are expected to actively search for the information they need and be able to understand it, something which requires active consumers with interest, time and expertise knowledge. Despite being called smart, the meters do not include information such as pricing or current electricity consumption, and a consumer who wants to find out how much electricity a household has used during a specific period of time has to do this manually.

Still, the smart meters are vague enough to allow for local tailoring (Star 2010). Among the consumers we observed, those with more expertise in the area struggled to understand the smart meters and helped each other to fit them into their daily practices which included other kinds of smart home devices, electric cars, solar panels and automated systems for heating. These consumers interpreted the smart meters in a way which worked with their daily practices (Star 2010). The consumers with a more average, layman, profile wondered about the advantages with the new meters, and did not see any improvements. They were primarily interested in the ability to find information about their actual electricity consumption in relation to electricity prices, and found this not in the smart meter, but in an assemblage of (other) devices which enabled them to follow up and plan for their electricity consumption. It seems clear that the consumers who were most capable to use the smart meters to their own advantage was those who could understand the technical language expressed by the grid operators and the electricity suppliers, and who had the time and resources to make the smart meters part of already established energy practices in their homes. The consumers have to understand this technical language (an expression of specific interpretations of the smart meters made by for instance the Swedish Energy Markets Inspectorate, grid operators and electricity suppliers), relate this to the smart meters, and interpret this to their own local practices, in other words, they have to be able to "tack back-and-forth" between the smart meters' vague identity, and their own, more specific interpretation (Star 2010).

This points to the unequal power relations which the smart meters are involved in, discussed by Lovell et al. (2017). It seems as though the government, the authorities, and the energy market actors (the grid operators and the electricity suppliers) are those with the main ability to drive the process, while the consumers were not invited, and had less possibility to influence the situation. The authorities and the energy market actors furthermore seem to be interested in keeping existing power relations in place, thus keeping consumers out of their current practices, out of their responsibilities.

7 Conclusions and Suggestions for Further Research

In this study we were interested in how different actors understand the smart meters and fit them into their locally situated practices and contexts, and we analyzed the smart meters with the concept of boundary objects as an analytical lens with the purpose of describing and explaining tensions between actors regarding intended use and actual use of smart meters. Based on three different practices (policy-driven smart meter practices, utility-driven smart meter practices, and user-driven smart meter practices) we have focused mainly on the Swedish government, the Swedish Energy Markets Inspectorate, grid operators, electricity suppliers, and consumers. Based on the empirical material, we can see that these different actors have different interpretations of and interests in the smart meters, and are consequently involved in different practices surrounding these. Out of the mentioned actors, the consumers, who were underscored as central by the government, were not included in the development of smart meters while other actors were able to control the process of development and roll out of the meters. From the specific research question asked which was: What do different actors expect from smart meters? It can be claimed that implemented smart meters does not really fulfil the expectations that consumers has and that there is both a need and a possibility to further develop value-added services by the use of smart data. The empirical material that we have taken part of indicate that information provided by the Swedish Energy Markets Inspectorate, as well as the grid operators and the electricity suppliers have developed functional requirements which are reasonable from the perspective of their own practices and interests, rather than for laymen consumers. The technically ripe language in the information they provide requires that the consumers are active, interested, and technical experts. Some of the formulations also show that the grid operators and the electricity suppliers are careful to delineate their own responsibility in relation to the consumers, indicating that they are not interested in inviting consumers as actors in the grid, understood as a technical rather than sociotechnical. Furthermore, from a consumer perspective smart meters do not seem to be so different from the old, dumb, ones, and it can therefore be questioned what their presumed smartness is about.

In this study we have, due to a limited amount of space, not included those who produce, install and maintain the smart meters. Based on this we recommend that future research include these actors, as well as include deeper explorations of consumer practices. Another suggestion for future work is to ask questions regarding the smartness of the smart meters; "smart for whom?" or "smart from whose/which point of view?" Finally we suggest further research about power relations between the actors involved in the smart meter context.

References

Adams, S., Kuch, D., Diamond, L., Fröhlich, P., Henriksen, I. M., Katzeff, C., Ryghaug, M. & Yilmaz, S. 2021. Social license to automate: A critical review of emerging approaches to electricity demand management. *Energy Research & Social Science,* 80**,** 102210.

Avancini, D. B., Rodrigues, J. J., Martins, S. G., Rabêlo, R. A., Al-Muhtadi, J. & Solic, P. 2019. Energy meters evolution in smart grids: A review. *Journal of cleaner production,* 217**,** 702-715.

Batalla-Bejerano, J., Trujillo-Baute, E. & Villa-Arrieta, M. 2020. Smart meters and consumer behaviour: Insights from the empirical literature. *Energy Policy,* 144**,** 111610.

Bergman, M., Lyytinen, K. & Mark, G. 2007. Boundary objects in design: An ecological view of design artifacts. *Journal of the Association for Information Systems,* 8**,** 34.

Buchanan, K., Banks, N., Preston, I. & Russo, R. 2016. The British public's perception of the UK smart metering initiative: Threats and opportunities. *Energy Policy,* 91**,** 87-97.

Buhl, H. U. & Weinhold, M. 2012. The energy turnaround: a real-time experiment allowing no failure or a major opportunity for our economy? : Springer.

Corbett, J. 2013. Using information systems to improve energy efficiency: Do smart meters make a difference? *Information Systems Frontiers,* 15**,** 747-760.

Doolin, B. & McLeod, L. 2012. Sociomateriality and boundary objects in information systems development. *European Journal of Information Systems,* 21**,** 570-586.

Forgues, D., Koskela, L. & Lejeune, A. 2009. Information technology as boundary object for transformational learning. *Journal of Information Technology in Construction (ITcon),* 14**,** 48-58.

Gal, U., Lyytinen, K. & Yoo, Y. 2008. The dynamics of IT boundary objects, information infrastructures, and organisational identities: the introduction of 3D modelling technologies into the architecture, engineering, and construction industry. *European journal of information systems,* 17**,** 290-304.

Ghazawneh, A. & Henfridsson, O. 2013. Balancing platform control and external contribution in third-party development: the boundary resources model. *Information systems journal,* 23**,** 173-192.

Goel, S. 2015. Anonymity vs. security: The right balance for the smart grid. *Communications of the Association for Information Systems,* 36**,** 2.

Gungor, V. C., Sahin, D., Kocak, T., Ergut, S., Buccella, C., Cecati, C. & Hancke, G. P. 2011. Smart grid technologies: Communication technologies and standards. *IEEE transactions on Industrial informatics,* 7**,** 529-539.

Hargreaves, T., Nye, M. & Burgess, J. 2010. Making energy visible: A qualitative field study of how householders interact with feedback from smart energy monitors. *Energy policy,* 38**,** 6111-6119.

Johansson, B., Granath, M. & Melin, U. 2022. Smart meters and demand side management in smart grids–exploring challenges and outlining future research directions. *European Conference of Information Systems (ECIS).* TImisoara , Romania: AIS.

Ketter, W., Collins, J., Saar-Tsechansky, M. & Marom, O. 2018. Information systems for a smart electricity grid: Emerging challenges and opportunities. *ACM Transactions on Management Information Systems (TMIS),* 9**,** 1-22.

Kopytko, N. & Perkins, J. 2011. Climate change, nuclear power, and the adaptation–mitigation dilemma. *Energy Policy,* 39**,** 318-333.

Kranz, L., Gallenkamp, J. & Picot, A. 2010. Power control to the people? Private consumers' acceptance of smart meters.

Lazoroska, D., Palm, J. & Bergek, A. 2021. Perceptions of participation and the role of gender for the engagement in solar energy communities in Sweden. *Energy, Sustainability and Society,* 11**,** 1-12.

Lovell, H., Pullinger, M. & Webb, J. 2017. How do meters mediate? Energy meters, boundary objects and household transitions in Australia and the United Kingdom. *Energy research & social science,* 34**,** 252-259.

McGowan, F. 2011. Putting energy insecurity into historical context: European responses to the energy crises of the 1970s and 2000s. *Geopolitics,* 16**,** 486-511.

Poderi, G., Bonifacio, M., Capacciou, A., D'andrea, V. & Marchese, M. 2014. Smart Meters as boundary objects in the energy paradigm change: the CIVIS experience. *A Matter Of Design. Making Society Through Science And Technology***,** 667.

Roth, L., Yildiz, Ö. & Lowitzsch, J. 2021. An Empirical Approach to Differences in Flexible Electricity Consumption Behaviour of Urban and Rural Populations—Lessons Learned in Germany. *Sustainability,* 13**,** 9028.

Shaner, M. R., Davis, S. J., Lewis, N. S. & Caldeira, K. 2018. Geophysical constraints on the reliability of solar and wind power in the United States. *Energy & Environmental Science,* 11**,** 914-925.

Star, S. L. 1989. The structure of ill-structured solutions: Boundary objects and heterogeneous distributed problem solving. *Distributed artificial intelligence.* Elsevier.

Star , S. L. 2010. This is not a boundary object: Reflections on the origin of a concept. *Science, technology, & human values,* 35**,** 601-617.

Star, S. L. & Griesemer, J. R. 1989. Institutional ecology,translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social studies of science,* 19**,** 387-420.

Star, S. L. & Ruhleder, K. Steps towards an ecology of infrastructure: complex problems in design and access for large-scale collaborative systems. Proceedings of the 1994 ACM conference on Computer supported cooperative work, 1994. 253-264.

Swedish Government 2018. Next generation smart meters can be introduced in Sweden.

The Swedish Energy Markets Inspectorate 2015. Functionality demands on the future's electricity meters [Funktionskrav på framtidens elmätare]

Tilson, D., Lyytinen, K. & Sørensen, C. 2010. Digital infrastructures: The missing IS research agenda. Research commentary. *Information systems research,* 21**,** 748-759.

Walsham, G. 2006. Doing interpretive research. *European journal of information systems,* 15**,** 320-330.

Warkentin, M., Goel, S. & Menard, P. 2017. Shared benefits and information privacy: what determines smart meter technology adoption? *Journal of the Association for Information Systems,* 18**,** 3.

Wunderlich, P., Veit, D. J. & Sarker, S. 2019. Adoption of sustainable technologies: A mixed-methods study of German households. *MIS Quarterly,* 43.