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Abstract

This study contributes a comparative analysis of eleven Danish smart grid experimental projects with household involvement. The analysis describes the scripts for the future smart grid interaction investigated in the examined projects, the approaches to user representation, and the project findings concerning consumers and smart grids. Three main dimensions of the scripts are identified and discussed: economic incentives, automation, and information/visualization. The methods employed for the development of user representations are primarily technical and techno-economic. While our analysis confirms previous findings that economic rationales and automation are central elements of smart grid scripts, the analysis also shows that there is considerable variation in the details of the scripts investigated. Our findings suggest that it may be useful for future smart grid projects to be more systematic and explicit in the analysis of household user perspectives and may consider a broader set of methods in this regard.

1   Introduction

Visions of smart grids as a central aspect of future energy systems have been on the societal and political agenda for more than a decade in some countries. While these visions imply changes and smart technologies for both the production and consumption aspects of energy systems, most development efforts have placed little emphasis on the latter. This lack of emphasis is striking as smart grid visions place new demands on the consumption side that is expected to supply a substantial amount of the flexibility needed for smart grids (Grijalva & Tariq, 2011).

This study offers a comparative analysis of experimental smart grid projects based on household consumers in Denmark. Building on the STS field (social studies of science, technology and society), the study employs the concept of scripts proposed by Akrich (1992) and identifies how such projects approach consumers, which scripts for the future interplay between smart grid and consumers they investigate, and what knowledge on the consumer-smart-grid relationship they establish. The study in turn identifies characteristics of the smart grid development community and of consumer–smart grid relations. Our focus lies exclusively on projects based on actual real-life experiments conducted in households over longer periods of time, thus addressing the challenge of moving from the visions and idealized images of consumers to real consumers and real use contexts.

The study complements other studies of experimental smart grid projects by comparing the scripts, user representation techniques, and findings of the different projects.

It has been identified that smart grid projects primarily address the managing of loads imposed on the grid by consumption (Christensen et al 2013; Niesten & Alkemade, 2015), and there is a bias towards economic incentives, the commodification of consumer flexibility and a dominant image of household users as primarily rational economic consumers (Verbong et al. 2013; Abi Ghanem & Mander 2014, Strengers 2014; Ballo 2015). Nevertheless, spaces for more open reflection and experimentation in terms of the roles and practices of household consumers in connection with smart grid flexibility have also been identified (Higginson et al. 2014; Schick & Gad 2015). Our study parallels a growing number of studies on consumers and smart grid-related energy consumption practices based on every-day life approaches and practice theory (Strengers, 2013, Higginson et al., 2014) with a focus on experimental projects (Powells, Bulkeley, and McLean 2015).

Denmark is an interesting case because of the challenges it faces due to the significant and increasing share of wind-power in its electricity systems, which account for approximately 40% of the country's electricity consumption (Energistyrelsen 2016). Expansion to over 50% by 2020 is planned. This generates special demands on the flexibility required on the consumption side. Furthermore, Denmark has invested significantly in smart grid research and can be considered among the leading countries in the field with one of the highest number of smart grid projects with a focus on smart homes and consumers relative to other European countries (Covrig, et al., 2014).

In the following section, a background for studying experimental projects is presented followed by a section on the methodology used. The results section opens with a description of our overall findings followed by a more detailed account of the main themes identified in the projects.

1.1   Users, scripts and experimental projects

The concepts of scripts and user representations originate from the sociology of science, technology and society that proliferated in the 1990s. These studies showed the complex and essentially socio-technical character of technological development whereby technical and material aspects and social and cultural aspects are deeply integrated and where technological development appears in interplay between actors. Technology developers and innovators build understandings and visions of the future into the technical objects that they construct. "A large part of the work of innovators is that of "inscribing" this vision of (or prediction about) the world in the technical content of the new object. I will call the end product of this work a "script" or a "scenario"" (Akrich 1992). Scripts define an (socio-technical) order around objects and specify roles for actors interacting with objects, including users. Scripts thus contain *representations of users* as technology developers typically keep specific use practices and user competences in mind (Ozaki, Shaw, and Dodgson 2013). Through these, scripts structure and constrain future uses and users of technologies. Potential users do however not necessarily *subscribe* to a script immediately. Often longer interactions and negotiation processes occur whereby potential users to a smaller or larger degree deviate from the prescribed script (or reject it). Through this, users can contribute to a new *description* of technologies and to a *re-inscription* of new qualities in scripts (Akrich and Latour 1992).

A related group of studies on the sociology of expectations in science and technology innovation has highlighted the important role of expectations and visions of future technologies and how their use shapes present-day activities and prioritizations (Borup et al., 2006). Compared to the concept of expectations, the script concept draws more attention to technical objects and to experimentation.

User representations in technology development activities are typically simplifications compared to the multi-faceted and complex character of real people and real use situations. For example, Lewis (2015) through a study of the design of dwellings for the elderly identified that the real needs of the elderly are far more diverse than the features inscribed into houses through designers' scripts based on imagined users.

Many techniques for the generation of user representations have been observed. Experimental projects based on user and consumer testing are among them. Other techniques include, for example, market surveys, opinion polls, the adoption of representations from other products that are considered to have something in common with new technologies, after-sales consumer feedback, expert assessments (e.g., consumer or market experts) and the study of personal use experiences of technology developers themselves (Akrich 1995). The latter technique is used more often than what might be believed at first glance.

It can be argued that experimental projects based on users and consumer tests, with their direct interactions between technological objects and real persons, have the potential to closely approximate real use situations. However, this is dependent on how experiments and tests are carried out in practice, and they will always involve a certain level of framing and bias. Skjølsvold & Lindkvist (2015) showed how intentions of user-centred design and user participation in a European smart grid demonstration project were in practice overshadowed by the technology developers' images of the users. Similarly, Abi Ghanem & Mander (2014) through another European smart grid project identified that it is the expectations of project engineers and designers of future household users as economic rational consumers that structure technological design and household experiments. The authors call for a more open and iterative design process through which real users are considered.

The important role of experimental projects has been also noted within related theories of sociotechnical change, for instance, the multi-level perspective (Geels, 2004), which includes three overall levels: Niches, the micro level, with protected incubation spaces with experiments and learning about new radical innovations; Regimes, the meso level, consisting of the stability of existing socio-technical systems and their sets of rules and institutions; and Landscapes, the macro and background level of the wider exogenous environment. Experimental projects involving heterogeneous actors, such as users, producers and public authorities, are shown to play an important role in the development of technological niches that can challenge existing regimes. Similarly, scholars of strategic niche management (SNM) have noted the central importance of real-life experimental projects for the development and diffusion of new technologies and innovations (Kemp et al. 1998). SNM is developed to particularly serve management of innovations that are "(1) socially desirable innovations serving long-term goals such as sustainability, (2) radical novelties that face a mismatch with regard to existing infrastructure, user practices, regulations, etc." (Schot & Geels, 2008). Smart grid technologies fulfil these two requirements, and real-life experimental projects can be expected to play an important role in the transition towards smart grid-based energy systems.

2 Methodology

The present study employs the concepts of script and user representations in an analysis of experimental smart grid projects. The identification of relevant smart grid experimental projects first involved a database search and the creation of a large list of potentially relevant projects. Second, an initial analysis of project material was conducted, which in some cases revealed other projects. An additional search for projects was then carried out, e.g., by consulting selected researchers and experts. Several databases were used in an iterative process of reaching the final set of projects. The most expedient were the following:

- The project catalogue of Energinet.dk (the grid responsible organization) and the Danish Energy Association on the future electricity system (Energinet.dk & Dansk Energi, 2011)
- The database of projects funded by energy research and development programmes in Denmark (www.energiforskning.dk)
- The smart grid database of the European Commission's Joint Research Centre (Giordano et al., 2013 and ses.jrc.ec.europa.eu)
- The EU CORDIS database on EU funded projects (cordis.europa.eu)

Through these searches, a list of 43 projects was created. Many projects were, however, excluded for various reasons, e.g., lack of actual consumers involved, experiments not taking place in real life household settings, a lack of reported results, or results not meant for public use. The final list of projects includes 11 projects (see Table 1). This study can be considered to thoroughly cover projects that are public and that have received funding from national or international programmes. Moreover, a number of projects completed by energy companies are included, but additional projects completed by private companies may exist. Our empirical study covers the period running until 2014, including a limited amount of additional material for 2015.

The analysed project material included project documents: project descriptions and reports, plans, and manuals or similar documents on the design and contents of experiments involving household consumers. In addition, project reports presenting descriptions of results and outcomes of the examined experiments were used. In some cases [4, 11], additional information on the specific set up of the experiments was obtained through personal communications with members of the relevant project teams due to practical questions regarding this issue. We conducted a document analysis where sources, see Appendix 1, were scrutinised to identify patterns across different projects. This process involved a general examination of documents followed a focused re-reading of the data for the construction of categories and themes (Bowen 2009).

The analysed project material serves as an original description of scripts and user representations used in the examined experiments and disseminated in the smart grid development community. It is a formalized and usually systematic account of the intentions and contents of the studied experiments. The limitation is that our analysis, especially with respect to the results of the experiments and user reactions to the scripts, is based on the project teams' representation, filtering and interpretation of the household activities.

The contents of the material were analysed with respect to the following:

- Which actors are carrying out the projects – who are the project leaders and which experts direct the experiments with the household consumers?
- Which approaches and techniques of articulation of user representations do the projects employ?
    o What technical arrangements and equipment (software and hardware) are used in the experiments and how are they integrated with the households?
    o What methods for analysing and evaluating experiments with household users are used?
- What scripts for future interactions between smart grid technologies and household consumers appear through the examined projects?
- What conclusions concerning smart grid and household users do the projects draw – do we see a de-scription or subscription to the presented scripts?

Through our first round of analysis, overall themes and similarities and differences between project approaches were identified. Through our second round of analysis, activities of different themes were analysed in detail, and project findings on certain themes were juxtaposed. Based on this, we present our synthesis and discussion of our results.

Project title:	ID	Project duration (years)	Duration of field test (months)	Number of households	Quantitative, technical data	Question-naire data	Qualitative data (other)	Economic incentives	Automation	Information/ visualization	Technology
Automation systems for Demand Response	1	3	24	500	X	-	X	X	X	X	Electric heating; automation
Dynamic grid tariff - Charge stands	2	n.a.	6	18	-	-	X	X	-	-	EVs; charge stands
Demand as Frequency-controlled Reserve	3	3	11	28	X	X	X	-	X	X	Automation to control individual loads ('smartbox'); electric heating
ECOGRID-EU	4	3	36	1800	X	X	X	X	X	X	HPs, electric heating; real time signals
EDISON	5	n.a.	3	13	X	-	-	-	X	-	EVs and charging functionalities
Energy Forecast	6	3	5	558	X	X	X	X	-	X	Indication of electricity prices
From wind power to heat pumps	7	2	24	300	X	-	-	X	X	-	Automatic control of HP; consumption measurement
Intelligent remote control of individual heat pumps (IFIV)	8	2	2	4	X	-	-	X	X	-	HP; automation; sensors
Prøv1elbil	9	3	3	80	-	-	X	X	-	-	EVs
Test-en-elbil (ChooseCom)	10	n.a.	3	1578	X	X	-	-	-	-	Charging; EVs
The e-Flex Project	11	n.a.	12	119	X	-	X	X	X	X	HPs; automation; consumption visualization

Table 1. Column 4-8: Approaches and techniques of user representation used in the experimental project field tests with household consumers. (Size and data types collected concerning the consumers. "n.a." indicates: no information available.) Column 9-12: Approaches used in the projects and major technological elements involved. EV = electric vehicle, HP = Heat pump

3 Results

In the following we first present our analysis results concerning the approaches and techniques of user representation employed in the experimental projects. Smart grid scripts investigated through the projects are then compared and common themes are identified. Major themes are discussed in further detail, including the projects' findings and conclusions on the themes.

3.1 User representation techniques

Almost all of the projects use quantitative, technical measurements, e.g., of energy consumption and of the use of different technical components and tools, as central techniques for the articulation of user representations, see Table 1. Our analysis shows that the projects employ a technology-driven approach to household users with a focus on testing ready-made technologies rather than on improving technologies by including consumers. In most cases, experts leading the experiments with household consumers are engineers. In addition, this strong emphasis on technology-driven approaches might also be related to the fact that the majority of projects [1, 2, 4, 5, 7, 8, 11] are led by energy companies or by other energy-system actors, and consumers are rarely included in grid development. This current technology-driven trend in smart grid development has been highlighted previously (Nyborg 2015).

In two projects, social science experts carried out experiments [4, 11] and five viewed consumer behaviour and social configurations of technology as being as important in the smart grid learning process and as part of the technical setup employed [2, 6, 9, 10, 11]. These projects report an interest in identifying constructive suggestions for further development of the technology, relevant consumer incentives, and consumer advantages and disadvantages in the recommended designs. These projects are often attentive to the fact that there can be important differences between consumers [4, 6, 11].

Three of the five projects with a focus on behavioural aspects investigate the use of electric vehicles (EVs) and smart charging [2, 10, 9]. They address how EVs can fit into households' everyday lives either in terms of specific use patterns, such as practical problems (e.g., range, charging, and safety) and pros and cons relative to normal combustion-engine cars, or in terms of values, such as flexibility, freedom, spontaneity, confidence and environmental considerations. Only two of the behaviour-oriented projects show a strong emphasis on household devices and their use in everyday life [11, 6].

Some of the behaviour-oriented projects identify that users respond differently to smart grid technologies and are motivated by different factors. It is highlighted that if the willingness towards smart grid technology is to be advanced, openness to the diversity and the different motivations of the users should be considered. One project finds that the most widespread rationale across all user groups is related to the environmental effects of energy consumption [11]. Other projects find that economic rationales are among the most common [6, 1]. In one project, it is further concluded that the new technology changes the roles within families, and it is identified that some of the experimental setups used are more family-oriented than others that target individuals. This project emphasizes that the new technology examined must be viewed as an intervention into households [11].

A number of projects identify a learning process that occurs in households. Two projects find that level of knowledge regarding household consumption, electricity markets, prices, and electricity system loads increases considerably [11, 6].

3.2   Contents of the scripts

The second part of the analysis discusses the contents of the scripts presented to the households. The analysis confirms that a core element of the smart grid projects' scripts is the change of households' energy consumption to become more flexible according to the needs of the smart grid. This has been reported previously (e.g., Nyborg and Røpke (2013)). All projects exhibit this perspective. Three overall approaches for creating flexible consumption are identified in the scripts. They are the following:

1. Economic incentives - consumers as economic, rational entities
2. Automation - automatic steering and control of household energy units
3. Information/visualization - energy information and consumer feedback as central factors

The experimental projects have significant focus on one, two, or all of these dimensions. Table 1 provides an overview of the projects and the addressed approaches of consumer-smart grid interaction.

Another main finding pertains to the fact that the scripts of most experimental projects integrate major new electricity consuming components into the households. The majority of the projects examined involve heat pumps (HPs), electric heating, or EVs, see Table 1, implying considerable changes to energy consumption patterns in technical terms and increased electricity consumption, which might enable an increased consumption of energy from renewable sources. This poses great challenges to the traditional power system (Kobus et al. 2015). In the following, script details with respect to the three overall dimensions are described.

3.2.1 Economic incentives

The majority of projects assume economic incentives to be a central element of the script of future smart grids and a key factor for creating flexibility established through electricity prices that vary over time (dynamic prices). Here, the main variation lies in the complexity of the pricing structure and in when prices are communicated to the consumers. The electricity spot market (Nord Pool) is used in the most of the projects as the wholesale price, representing less than 20% of the electricity price in Denmark. Some projects [2, 4, 11] use dynamic net tariffs to increase electricity price variations. Here, fixed categories (cheapest at night and most expensive in the daytime) of dynamic net tariffs are applied, announcing the electricity price one day ahead and thus increasing the level of variation relative to projects with one varying component, the spot price. With this combination of dynamic net tariffs and spot market prices, the complexity increases.

The most complex pricing system uses 'real-time' pricing whereby users obtain a signal with the price of electricity 5 minutes before it occurs, i.e., very short notice compared to that offered to users with spot contracts and net tariffs [4]. The simplest approach to economic incentives was achieved by giving participants (with a flat rate contract) a 50% discount per kWh between midnight and 6 o'clock in the morning [9].

For certain projects, specific price variations are not communicated continually to consumers, who are not expected to keep track of prices in detail. Instead, varying prices are used as a parameter to control specific units in the households, e.g., HPs [1, 7, 8]. Thus, household expectations and the de-scription of variable prices vary among the examined projects. On occasion, households are expected to keep track of prices [4, 6, 11, 2], and for other projects they are expected to wait for a bill to receive consumption data [1, 3, 5, 9].

Project conclusions regarding economic incentives to some extent confirm previous results where consumers have been shown to prefer real time prices combined with automation rather than other 'time of use' schemes (Dütschke and Paetz 2013). For instance, two projects find that economic incentives and automation in combination can lead to increased flexibility in energy consumption [1,11]. Furthermore, changes were observed in household consumption patterns due to a combination of price incentives and price information visualizations [1,2].

Although an increased degree of flexibility appears in a number of projects, means other than economic incentives are causing this change. A number of projects identify that household consumers view dynamic prices positively in theory. In practice, the situation is more complex, and a partial rejection and de-scription of price scripts appears. For instance, one project [11] concludes that *"a relatively large segment*

of customers is not sensitive to variations in electricity pricing, and other incentives may play a more influential role in customers' procurement behaviour" (Dong Energy Eldistribution, 2012*). Other incentives include for instance: an interest in being more environmentally friendly and in reducing energy consumption. Moreover, technical interests in the new energy technologies and in how they can be employed were found [1,11]. In addition, an interest in supporting responsible development in the local community and energy system is observed [4]. Early adopters consider the development of a green image to be more important than lowering costs (Verbong, Beemsterboer, and Sengers 2013), which may explain the overall lack of interest in pricing schemes found even though project participants were generally interested in changing their consumption patterns.

Powells et al. (2014) investigated a range of households engaged in a pilot project where they received a time-off-use (TOU) tariff to direct consumption away from peak hours. The results show that while TOU may have some effect on household consumption patterns, many energy-consuming practices are difficult to change. These difficulties were confirmed in this study. One project identifies that approximately 40% of households do not in practice have the ability to act flexibly with regards to energy consumption despite expressing an initial interest in doing so. Interestingly, one project also showed that when a distinction is made between necessities (cooking, heating, etc.) and luxurious practices (hobbies, social life, etc.), participants are mostly willing to change consumption practices related to necessities.

3.2.2 Automation

In agreement with the findings of Strengers (2013), our study finds no consensus among engineers and developers of the energy sector as to the scripts of automation and control in smart grid households. A previous study on people's views on remote control (RC) and variable prices based on focus groups has shown that RC can have an effect on the sense of control that consumers have over their home (Fell et al., 2014).

Seven of the eleven projects concern automation in smart grid scenarios and investigate different types of technologies used for the automatic control of household energy units. The primary purpose of automation is to serve the needs of the power system and to create flexibility on the demand side. Consumer benefits from automation are typically not the primary goal. However, for many of the projects it is assumed that automation in the sense of little or no interaction with energy equipment is in the interest of consumers. This would imply the creation of discrete and unnoticeable technologies to increase levels of comfort in the home [1, 11].

New control opportunities for household users appear in some of the projects involving new settings for comfort preferences, e.g., temperature and maximum temperature variations for rooms in connection with electric heating and HPs or preferred normal or maximum charging times in connection with EVs. Users can apply specific settings and can then leave the technology to work automatically, at least for a given period [4, 11]. In this way, such projects seek to integrate flexibility preferences of the consumers and the power system. One project [3] deviates by including a 'smart box' where steering and communication technologies are combined with consumer opportunities to connect additional electric devices. In practice, for example, freezers and pumps can be connected.

Automatic control is normally designed to occur outside of households with electricity system actors managing and controlling the local flexibility. Of the seven projects examined, five automate on the basis of price signals alone or in combination with energy forecasts and technical signals about the state of the power system [1, 4, 7, 8, 11]. The rest use technical parameters only as a basis for automation. For these, households are expected to accept an automatic remote control script and to turn electric devices on or off without receiving special economic benefits or compensation [3, 5].

Remote control automation implies changes in the role distribution and relationship between household consumers and energy system actors. The experiments differ on this point, for example, with respect to whether an 'aggregator' role is established[1]. This role has been found in other reviews of smart grid pilot projects and literature, see for instance Niesten and Alkemade (2016) focusing on value creation through a new constellation and integration of a variety of smart grid services. However, it is clear that the smart grid script with remote control automation implies substantially expanded and more complex technical interactions between households, energy companies and other actors of the electricity system. This implies a surrender of control from consumers to system actors. Much more information on the household energy systems and electricity consumption is delivered to system actors. A new role distribution appears through the technical smart grid devices, changing the relationship between electrical devices, consumers and electricity suppliers. While automated control might increase household control over their appliances, it may also introduce unwanted forms of control (Hargreaves et al. 2015). Furthermore, automated forms of control may change dynamic within families and entail increased control over family members through increased opportunities to control appliances (Nyborg 2015). Issues of data security, privacy and data access rights are addressed in some of these projects, though primarily as a technical issue. A broader discussion of access rights, information ownership, etc., is not undertaken.

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[1] An 'aggregator' monitors and aggregates the consumption of several consumers and based on this manages the interplay between consumption and electricity systems.

Not all projects report specific conclusions regarding the automation aspects of the experiments with consumers. Of those that do, the general findings are first that consumer comfort levels can be maintained in most cases. They are not significantly reduced as a result of automatic control [1, 11]. Second, automation is central to changing consumption and creating flexibility (as mentioned above) not only in combination with price incentives but also in other cases. Third, it is found that many of the involved consumers view automation equipment positively and to a large degree accept the script, including being controlled by an outside actor [1, 11]. Consumers vary on this issue however. One project concludes that consumers hold generally neutral to moderately positive views of automatic control [4].

The most positive results tend to appear from setups where a combination of user control and automatic control is established. This is, amongst other things, observed in a direct comparison between two automation systems. Being offered a number of options for setting the room temperature is viewed positively and as useful by consumers. The ability to override automatic control, e.g., concerning temperature levels or slow or fast EV charging, is viewed as an advantage (even if it is not often used) [4].

While households do not seem to mind having their heating devices (HPs and electric heating) remotely controlled, automatic EV charging was not equally appreciated. Automatic control is found to work best when applied to energy components such as HPs and electric heating while the automated control of other devices, such as freezers, fridges, dryers and pumps, raised problems for the participants. Some of the projects conclude that EVs and automated charging control are not easily integrated into the social practices of users' everyday lives, as core values regarding flexibility and confidence are not fulfilled in such cases [2, 9].

Automation scripts do not necessarily imply passive users. The picture is more complex than this. A number of projects show active engagement in de-scription and re-inscription processes among the users, e.g., the connection of other devices, even after severe problems, such as pump and freezer malfunctions, in some cases [1, 3].

3.2.3 Information/visualization

Research on visualization and information equipment has previously focused on how specific visualization tools may affect energy consumption (e.g., D'Oca et al., 2014; Darby, 2006; 2010). It has been shown that remote control visualization from external actors is typically excluded. Our study supports these findings. The scripts include the visualization of household consumption but not detailed information on outside automation and control.

Five projects include information and visualization equipment in the smart grid script. Visualisation equipment varies considerably from project to project. Such equipment normally informs the state of the electricity grid (often the prices) or of the state of a household's energy consumption and energy equipment. Sometimes, equipment measures opportunities for consumer feedback to the smart grid system or allows one to set preferences for control and comfort (e.g., concerning temperature levels) [3, 4, 8, 11] or to control the electricity consumption of individual devices [11].

In addition to written text and numbers, graphic visualizations and signals are included in some projects. Many different forms of media are used for communication purposes, including in-home boxes and displays, web-based systems accessed through consumers' computers or smartphones, text messages (SMS) and e-mails, and social and mass media (TV broadcast).

Two projects [11, 4] include the most complex information and feedback systems. For one of them, the consumers are given a home automation portal installed on a tablet device or personal computer, which enables them to change settings related to their HPs, heating systems, and EVs, and are given monitoring devices attached to 'smart plugs' that are part of the system. They can choose between optimizing their energy consumption according to a) price signals; b) the amount of wind energy in the energy mix in the grid ('environmental signal'); or c) a balanced combination of the two. Furthermore, members participate in a Facebook-like social media platform where they can receive technical support from professionals and one another [11]. The second project seeks to test four groups, where three groups have access to pricing information, consumption data and bonus calculations through a web portal. Two of the groups are also given advanced home automation and information systems, each including yet another web portal with access to tailoring and pre-programming to maintain a preferred balance between comfort, consumer flexibility and cost savings [4].

Two projects are based on a box ('Electronic Housekeeper') equipped with hardware and software that controls linked appliances automatically or manually based on displayed price signals [1, 3]. The simplest visualization tools include daily e-mail or text messages or a webpage presenting information on electricity price variations for the coming 36 hours. One project tested local TV weather reports with energy forecasts of prices and delivered an in-home box with a clock-like display showing relative electricity prices for the coming hours based on three different colours [6].

In most cases, the projects primarily report conclusions regarding changes in energy consumption and to a lesser extent address users' interactions and experiences with using the information and visualization tools. While such tools do not typically change consumption patterns by themselves, they are among important

contributing factors. Our study confirms previous research showing that visualization equipment plays an educative role in relation to electricity consumption (Hargreaves, Nye, and Burgess 2013). Visualization equipment functions as a 'mediator' between the abstract 'electrical world' and the 'real world' in the home. An interaction with such equipment encourages flexible consumption. It is identified that many consumers are more focused on their energy consumption habits and on acting in an environmentally friendly manner after the project [10].

The most positive and unambiguous results are found in connection with relatively simple information and visualization tools, such as the clock-like light signal display and e-mails/text messages. Most consumers view such tools positively. They use the information delivered and understand it, and they often make changes to their consumption behaviours based on such input. Information delivered through mass media (TV) also shows positive results [1,6].

By contrast, conclusions regarding complex consumer interfaces and information tools are less straightforward. Web-based tools are typically used by a smaller share of consumers (in [4], for example, approximately 25-30%). Moreover, satisfaction with the use of websites varies. Similarly, consumers have mixed views of advanced in-home boxes [1, 3, 11]. Scholars have previously highlighted that several pilot projects in Europe have involved the use of smart metres and Smart Energy Monitors to investigate how increased information (regarding consumption) affects behaviours. Usually, increased information results in little or no savings in electricity use among households. Rather than dismissing such informative technologies due to these absent savings, scholars have argued that such information technologies are contributing to energy citizenship. With these devices, citizens can become informed and contribute to more sustainable energy consumption. Thus, such devices can be viewed as engaging and having performative effects (Throndsen & Ryghaug, 2015).

4 Conclusion

Our comparative study of experimental smart grid projects reveals overall similarities in scripts and in representations of household users. The experiments on economic incentives, automation and information/visualization support the same overall view of consumption flexibility that serves the grid and expands electricity consumption through new consumption technologies. A view of the smart grid development community as interconnected and relatively homogeneous is supported by the fact that the projects in a number of cases are connected and overlap with participant organizations, with energy sector actors serving as central actors. The methods employed for the development of user representations

mainly include technical and techno-economic approaches. Social and behavioural approaches play a minor role.

Despite the similarities found, our study reveals considerable differences between the details of the scripts within the three overall dimensions, and it is clear that a general agreement on the main elements of smart grid technology has not yet appeared

Regarding economic incentives, several pricing schemes have been tested with limited consumer acknowledgement. There is a contradiction between project findings that economic incentives alone are not sufficiently important to consumers to change consumption patterns and the continued strong focus on this dimension. While results on scripts that involve the automatic control of energy units are more positive, some of these projects lack a systematic account of the users' perspectives. The variations in the scripts concern how the energy units are controlled, the degrees of user control, and which agents in the energy systems the households can interact with.

Regarding information/visualization, the scripts show great variations in complexity. The fact that simple interfaces are more widely accepted than complex solutions, e.g., using internet portals, etc., raises questions regarding whether a high level of complexity actually addresses household needs and interests despite energy learning outcomes that these solutions can initiate. Furthermore, regarding information/visualization, our study shows that experimental projects do not always systematically analyse the users' perspective.

The studied projects represent users at the household level rather than as individuals and as (passive) electricity consumers rather than, e.g., as active energy managers and contributors to the energy systems (prosumers) or as members of a local community or network, as is noted elsewhere (Verbong et al. 2013).

Experimental projects represent only one form of user representation technique. The considerable variation in the details of the scripts among the experimental projects is a point for further discussion within script studies more generally. A large number of choices and prioritisations are made by the project designers to establish the individual experiment. There is need for research that elaborates on the descriptions of smart grid scripts by users and on how such modifications (or rejections) are taken up by smart grid developers, eventually in new re-inscriptions with changed intentions and outcomes.

Our findings suggest that it may be useful for future smart grid projects to be more systematic and explicit in the analysis of household user perspectives and to consider a broader set of methods in this regard.

Greater flexibility gains than those observed through the studied projects are required, and a shift in focus towards benefits for users may be fruitful in pursuit of this goal.

5 References

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