# Conceptions of end users in current smart grid research and opportunities for further social scientific research on users in smart grids

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# Abstract

Many resources have been put into preparing our energy provision systems for a future with more distributed and intermittent energy production. Especially in Europe and the US a large amount of public research funds has gone to the research field of smart grids. Within policy communities and smart grid research communities there is a consensus that a changed user-system relation where users become sensitive to system level constraints is a key element of smart grids. However, the way this sensitivity is conceptualized and the nature of claims differs from one project to the other and sometimes even within research projects.

As the realization of smart grids becomes pressing the multitude of claims becomes a problem for the design of large scale demonstration projects and the planning of actual smart grid deployment. This fragmentation of research is recognized in existing reviews but so far there have been no attempts to handle it.

This paper suggests that classifying the research contributions according to the roles they assign to users and the theoretical concepts they employ to represent users can help in evaluating the validity of their claims, uncovering possibilities for synthesis of existing knowledge and seeing new possibilities for social scientific research where knowledge gaps appear.

Different user representations and user roles are found through a content analysis of project related documents from a selection of European and North American smart grid projects.

It is argued that differences between approaches can be found in: 1) The included time horizon; 2) The included social sphere; 3) Theoretical assumptions about behavior; 4) Theoretical assumptions about societal change.

# Keywords

Field trials, user studies, user behavior,

# 1. Introduction

## 1.2 The surge of smart grid research

‘Smart grids’ have come to be seen as a key solution to the challenge of integrating renewables in the energy systems. The buzz has been followed up by investments in research and development and in deployment of smart grid technologies. In the US the American Recovery & Reinvestment Act (ARRA) has so far resulted in $5.1 billion of smart grid related payments (ZPRYME 2013) and the total smart grid investment in the US has so far been $11.2 billion (Giordano & Bossart 2012). In Europe (EU 27 plus Croatia, Switzerland and Norway) more than €5 billion have been invested (Giordano et al 2011, Giordano & Bossart 2012). However, these numbers does not reflect a focused effort to pave the way for smart grids. As an example, Giordano et al (2013) note that if simple smart meters are excluded Europe has delivered a more modest €974 million from various public funding sources and a total investment of €1.8 billion.

## 1.2 Research on users: A small but important niche in smart grid research

This immense research activity has naturally generated a plurality of claims and visions about smart grids. However, it seems to be the consensus that the key novelty in smart grids is a change in the production-consumption relation calling for changes in consumption patterns at the end user side. Notably not a one off restructuring of load profiles, but rather an on-going increased sensitivity at the end user side towards technical issues at the production and distribution side. Differences appear when it comes to how (and when) this sensitivity is ensured: By automation, communication, education or by introducing consequences or positive incentives?

The scale of smart grid research projects varies from theoretical proofs and small experimental studies over simulations and broad surveys to field trials or large scale deployment of single smart grid technologies.

The main part of the conducted research addresses what novel technologies in monitoring, computation, communication and control can do. A smaller portion of the research addresses the relation to end users more directly by observing or modeling end user behavior at different scales. End users may be both private households and different commercial activities. In this paper we will address research on use and users in private households. Most of this research is focused on the individual. The most prominent example is studies of user responsiveness to different pricing structures.

Smart grids have also been studied by social scientists with an interest in the wider aspects of the human dimension such as innovation processes (Verbong et al 2013), transition processes (Verbong & Geels 2010), the institutional set up in energy markets (Schleicher-Tappeser 2012, Wolsink 2012), or in the strategic actions of stakeholders (Erlinghagen & Markard 2012). These contributions are, however, mainly commenting on the smart grid development and not so much contributing to it.

## 1.3 The construction of user roles determines the effect smart grids will have on consumption patterns

Wolsink (2012) problematize that the institutional changes that are needed to turn smart grid promises into reality are not addressed in the development of smart grid concepts. Drawing on the concept of ‘common pool resources’ Wolsink argues that changes in behavior only come about if users are handed real control of managing their resources as co-producers or co-owners. Furthering existing infrastructure and routines of metering, data collection, and feedback to the customers that reproduce an old notion of ‘demand side’ will restrain participation in smart grids, Wolsink claims. Wolsink’s argument raises a concern that the construction of roles may create a socially founded lock-in.

## 1.4 The technical and political context may have a subtle influence on what is researched

The condition of grid infrastructures, the specifics of institutions that govern them and past user experience with the level of delivered service are all decisive for what users have come to expect and what they perceive as their needs. The current state of affairs also shapes the policy goals and business opportunities identified by actors in and around the energy sector. This is also true for identification of smart grid research objectives.

Europe and North America differ in where the weight is put in smart grid research and development. In North America the focus is on general energy conservation and peak shifting while Europe has a much larger focus on aligning consumption with renewable energy sources (RES)(Mulder et al 2012). This difference is due to differences in the existing grids and in goal setting in the policy domain.

In North America grid infrastructure has been developed by private enterprises with a strong focus on balancing cost and sales whereas In Europe grid development has been handled by public entities. This means that electricity grids in North America in general have a lower capacity than in Europe. Further, especially the US has a higher potential for reducing electricity consumption simply because the final demand here is the highest in the world. As part of its efforts to reduce its climate impact the European Union has adopted and enforces targets for introduction of RES in the energy supply. As a result investments in small distributed generation technologies and in electrification of end used are growing and changing both the time and spatial characteristics of the supply and demand landscape hitherto handled by grid managers.

The political context is also active at a lower level. Organizations already involved in the energy provision systems or those hoping to expand their business with the introduction of smart grids may be actively pursuing narrow visions of the smart grid. Nyborg & Røpke (2013) discuss how user studies can be used to produce and validate narratives about the “aligned user” who profits from the solutions offered. This can be seen as a tactical move by actors in the provision systems to pave the way for system development. Nyborg and Røpke question whether possible counter effects are sufficiently accounted for in this process.

The design of research has an effect on the possible outcomes because it gives specific attention to some issues and excludes other. This is both an effect of what is in the interest of researchers and organizations involved and of the need for reduction of complexity that characterizes most if not all scientific practices. This precondition leads to challenges in the transfer of knowledge from one setting to another and also to a general uncertainty about the validity of scientific claims.

Hence, as context has some effect on what is investigated in research, we should pay attention to the different challenges smart grids are expected to solve in different settings and by different actors.

## 1.5 Research and development of smart grids needs more attention towards how claims about users come about and what can be inferred from them

An overview of existing smart grid research is a precondition for avoiding endless reproduction of already established knowledge. An overview of smart grid research and the different positions it offers is also of relevance to designers, policy makers and other stakeholders engaged in developing smart grids.

A handful of review studies have already attempted to report from or organize the existing research on users in smart grids: Some with demonstration projects as an offset (Gangale et al 2013), some with more narrow foci on dynamic pricing and feedback (Breukers and Mourik (2013), Flaim et al (2013), Strömback et al (2011), Foster and Mazur-Stommen (2010), Ehrhardt-Martinez et al (2010)) and some which directly address new user roles (Geelen et al (2013), Darby and McKenna (2012)).

Geelen et al (2013) ask to what extent current products and services empower users to become ‘co-providers’ in the energy system. They define this as being able to: 1. Use electricity efficiently; 2. Plan or shift electricity consumption to moments favorable to the energy system; 3. Produce electricity when favorable for the local grid; 4. Trade surplus self-produce of energy (Geelen et al 2013). Reviewing some of the smart grid technologies (products and services) available and a number of smart grid demonstrations the authors find that only a mix of products and services will allow end-users to full fill all four criteria (Geelen et al 2013). Geelen et al especially stress a vertical relationship between ‘core technologies’ (production or consumption units), ‘intermediary products and services’ (management in the home) and ‘services for energy management’ (context information and control signals) (Geelen et al 2013). The valuable lesson in Geelen et al’s line of argument is that it is a combination of awareness, physical objects and possibilities for action that allow for participation. This complements earlier work by Abrahamse et al (2005:238) which concluded that the effectiveness of antecedent interventions such as goal setting increase when they are combined with consequence strategies. Breukers and Van Mourik (2012) suggest designing interventions around the end-user characteristics rather than given technologies or price mechanisms. This infers that different user circumstances should be investigated and organized. While this is attempted e.g. through segmentation based on the lifestyles concept, the question remains whether users as groups or individuals are uniform enough to be organized this way (Breukers and Van Mourik 2012)? Foster and Mazur-Stommen (2012) report that in several real time feedback field trials a small percentage of users appeared to be more ‘cybernetically sensitive’ than others. This indicates that some users may be predisposed to respond or that they have successfully formed new habits with the introduction of new technology (Foster and Mazur-Stommen 2012). It also raises the question whether other groups of users may be made sensitive at all (Foster and Mazur-Stommen 2012)?

Similar to Geelen et al we suggest that isolated smart grid functions frame users in a way that does not reflect the multitude of suggested smart grids functions. Hence, the behavior of users in the system, or the role they perform, reflects the stimuli and possibilities for actions that are constructed in the specific system design rather than a full set of possible roles a user could take. However, design is not instrumental to behavior and design may be flawed. Fuzzy or absent behavioral responses does not necessarily reflect a clear user disposition against a specific intervention but might show that users are conceptualized in the wrong way.

Another aspect addressed by Geelen et al (2013) is that facilitation of overall change processes such as adoption of new technologies is an issue in its own right. Gangale et al (2013) report from European demonstration projects that problems with getting users involved reflect ‘lack of trust’ and issues with finding the right ‘motivational factors’. The issue of trust can be understood as skepticism towards certain markets or organizations (Gangale et 2013) but might also be a natural process of gradually becoming familiar with a new provision concept and new products and services (Geelen et al 2013).

We suggest that attention to the overall process of change is important in the interpretation of how users respond to smart grids. It is also relevant to take into account how current experiments involving users can change the context for the broader uptake of users by producing.

# 2. Scope and content

This paper is an attempt to map out existing smart grid research according to how it adds to the understanding of the role of users in (future) smart grids.

The paper addresses the following research questions:

1. What has so far been scientifically investigated about household users in smart grids in Europe and North America?
2. What are the knowledge gaps from a social science perspective?

The methodology below addresses how existing research has been uncovered and the level of detail investigated. This is mainly based on practical considerations and a simple operable definition of what smart grid related research is and is not. It also offers a typology of ‘users’, ‘user roles’ and ‘user representations’ used in the analysis of the content of project related documents.

The result of the content analysis is organized and unfolded using the typology. This serves as a basis for a discussion of how existing research may be connected or complemented by new research. Four themes inspired by social science are used to characterize the differences between approaches: 1) The included time horizon; 2) Theoretical assumptions about behavior; 3) The scale of the included/ relevant social sphere 4) Theoretical assumptions about societal change. Finally some implications for further social science research into smart grids are suggested.

# 3. Methodology

## 3.1 User roles and user representations

There is a rich variation in how the human side of the smart grid is denominated. Humans are not always directly mentioned but may be represented by something they do or something they are thought to be responsive to. When humans are directly mentioned they are mostly called ‘consumers’. This varies with research field and type of publication. Other examples are ‘households’, ‘citizens’, ‘consumer-citizens’, ‘users’, ‘prosumers’ and ‘agents’. In this text we will use the term ‘user’ to represent humans. This is just at name and does is not meant to imply any inert human qualities established in existing research fields. It also does not imply that the user is one individual. It may just as well be a group of individuals with a shared relation to the larger smart grid system.

We use the term ‘user role’ to describe the relation between the user and the larger system. We remain open to what can constitute a ‘user role’ but expect that it at the very least would involve some form of action on the user side. Or rather, the action the user is expected to perform. It will become clear that user roles can vary in what degree of ‘repetitiveness’, ‘mental activities’ and ‘use of artefacts’ that is presupposed.

The term ‘user representation’ is used for attributes assigned to users or taken to be representative for users in a given research context. “User representations” does not necessarily reflect actual use and users.

## 3.2 What can reasonably be regarded as smart grid research?

Smart grids involve many types of technologies; Some are physically distinct and located in the home, some are harder to read as they move around in public space, hang high in the air or hide ‘tugged away’ in controls rooms. Smart grids also relate to different ‘business-to-user’ relations. Essentially everything that consumes or could consume energy in the form of electricity has a possible relation to smart grids. Some technologies and business models are especially hard to position in relation to smart grids because they are familiar or share a lot of similar traits with known concepts or because they are often mentioned in relation to smart grids but never really unfolded in research or policy proposals. Examples of the former group is ‘home energy management’, ‘home automation’, ‘smart homes’, ‘electrical vehicles’, etc.

To avoid confusion between projects investigating smart grid issues and those focusing solely on separate issues such as: ‘Mobility’, ‘convenience’, ‘response to feedback on energy consumption’ or ‘energy efficiency’, we sampled projects by a narrow definition of smart grid research. Since our purpose was to evaluate research activities, our sampling strategy excluded broad Smart Grid policy documents from public authorities and other organizations.

The decision whether or not to include a project in the survey was based on the following definition:

Projects should either:

1. Be declared as smart grid related,
2. Include frequent information flows in relation to electricity loads back and forth between the home and some external entity,
3. Include external control of technologies in the home,
4. Examine situations where b or c is simulated or assumed as the context.

We did not discriminate between projects that came off as purely technical and those that had a more cross scientific approach to them. However, we only included projects that either:

1. Formulate a vision for or any kind of description of the role of users in the smart grid,
2. Initiate empirical investigations of user behaviour, attitudes or preferences – either in relation to field trials, experiments or in broad surveys,
3. Make claims about users based on empirical investigations or literature studies

Our initial ambition was to look for conceptually well-developed projects which included field trials with collaboration of research institutions and organizations in the energy systems such as e.g. utilities. However, in the end small academic studies and single broad surveys were also included as the research practices turned out to be more fragmented than expected.

## 3.3 The global context of smart grid research

We did not have a limited geographical scope in the survey but our attention to different regions did vary with the effort needed to find, acquire and digest documents: Hence most attention was paid to the Nordic countries and the UK where e.g. working papers and reports were easier to find and digest. Projects were only included if they were reported in English, Swedish, Norwegian or Danish language.

North America and Europe have the most activity in smart grid research. Within Europe, Denmark stands out in number of projects and in relative spending (Giordano et al 2013). With Australia as the exception smart grid research activities are few but growing in the rest of the world (Mulder et al 2012). China is reported to have the largest spending in smart grid development. However, this appears to be mainly in relation to expanding ‘raw’ grid capacity rather than advanced grid management.

The result of the sampling strategy was that European, North American (especially US) and Australian projects could be covered rather extensively. In this article we only report on North American and European projects.

## 3.4 Finding projects and attaining relevant empirical data

In general the search for relevant projects was conducted using the following different sources:

1. Existing surveys of smart grid projects (see appendix 1)
2. Public authority homepages
3. Databases on smart grid or energy research projects
4. Contacts within business and research
5. Simple online searches on Google.

Following this relevant documents or web texts were retrieved through:

1. Project homepages
2. Company homepages
3. Public authority homepages
4. An extensive search for academic publications within academic databases (using keywords, project acronyms and researcher names)
5. Simple online searches on Google (using keywords, project acronyms and researcher names)

The JRC (The European Commission’s Joint Research Centre) based database of European Smart Grid projects (reported in Giordano et al 2013) made it easy to gain an overview of European research efforts. The database includes current and completed projects but the main body of projects are on-going. Most European projects are well described and a variety of ‘deliverables’ are available for download on publically available project home pages. In the US the database of ARRA (American Recovery & Reinvestment Act) funded projects provided an overview of current smart grid projects and descriptions of overall research plans for each project. Completed US projects were found through web resources (smart grid focused online news media), review papers and references in project descriptions in current projects. It proved hard to find and acquire detailed research plans and reports on US projects online. In the US, a project homepages is often a subpage to a utility company’s homepage and rarely offer more than an overall project description and some short news on deployment progress. They seem to be designed for communication to media and field trial participants rather than for communication of research results.

## 3.4 Topics investigated in the content analysis

Prior to the sampling we had developed a coding strategy. In included the following three topics which are further defined below:

1. The imagined role of users in smart grids
2. Methods used to study users
3. Claims made about users’ behaviour, preferences, attitudes, etc. on the basis of research.

Topic 1 covers descriptions of users made in system descriptions, visions, scenarios, deployment plans etc. The focus was on what kind of behaviour (use, misuse, rule-following, investment, etc.) that is expected from users or on what sentiments, motives or (‘green’, ‘money-saver’, ‘scepticists’, rational man, etc.) rationality they are endowed with. It also covers whether users are considered to be central or peripheral actors or resources in the envisioned smart grid set up.

Topic 2 covers the different research techniques used in the study of users in field trials or in broader surveys: Monitoring of user behaviour, small quantitative surveys of user experiences or preferences, interviews about user experiences, large quantitative surveys of attitudes or preferences of possible users, focus groups with possible users, etc.

Topic 3 covers claims made about users’ behaviour, preferences, attitudes, etc. on the basis of the research (or on the basis of literature studies). Special attention was given to the results highlighted by the responsible authors.

The purpose of the content analysis was to establish how users have been conceived and investigated in smart grid research projects. This required looking for meaning structures in the sampled texts. Hence, the analysis was conducted by manually trawling the documents for descriptions or statements about users and descriptions of or references to employed scientific methods. In larger documents indexes and keyword searches were used to find relevant text passages and sections.

# 4. Results of the content analysis

The scientific work in projects consolidates user roles through the knowledge it produces. Either in the (theoretical) framework it formulates or in the claims it makes on the basis of empirical work. But the relation is not straight forward. Some user roles are backed by more than one research approach but some research approaches are hard to connect directly to any user role.

## 4.1 Observed scientific claims made about users

Claims made about users in smart grids are relatively few compared to the research activity; at least when it comes to communication of these claims in scientific journals. This is partly a result of the progress of projects but may also be an effect of the role of private funding and of an innovation agenda behind projects aiming more at producing business models than scientific results. This is most outspoken in North America.

Claims about users are mostly expressed through a user representation. This can be a number, a concept or in rare cases a description of practice. These user representations are taken to represent all or a smaller fraction of users. In table 1 the observed user representations are connected to research methods used to produce them and the research fields normally involved in producing them; the latter group being non-exclusive. The corresponding research fields are not always clearly stated in projects reports but can be in related academic publications positioning the projects’ findings.

Many projects have examined many different pricing schemes. The result is often a number expressing what users are willing to pay for something or the marginal effect of prices, rebates or punishments. In the US a lot of projects have tested how pricing schemes affect demand response from automatic load control of thermostats and air condition.

Many projects have also examined the effect of many different ways of conveying information. The success is mainly evaluated through demand response measurement. This includes different media (home visits, letters, phone calls, television text, meter displays, websites, in home displays, ambient devices,.. etc.), different timeframes (from real time feedback to periodical billing) and different levels of detail in information (energy consumption, prices, saving opportunities, tailored advice, energy audits, social comparison data, device specific energy consumption feedback.. etc.). In earlier studies various forms of information has been examined with or without a combination with pricing schemes. What characterized the projects we reviewed was that information was mostly combined with pricing schemes and that feedback was frequent (the latter is not a surprise as this was a precondition in our sampling strategy). Darby (2006) offers a distinction between direct and indirect feedback where direct feedback is data on the energy used and indirect feedback is the data on energy use processed with algorithms and/or complemented with historic data or data from other households.

A large group of narrow projects evaluate the smart grid readiness of users either by skepticism, awareness or stated willingness-to-pay. These indirect measures of the acceptance of smart grid technologies are used to examine beforehand the feasibility of different core technologies, pricing schemes or feedback devices.

The endpoint for research into complex social dynamics related to smart grids tend to be a ‘proof of concept’, i.e. demonstrating the feasibility of a given ‘intervention’. The set ups in these research activities often lack the richness of social context (short experiments) or the variation in how everyday life is performed by different individuals (few participants). A few studies offer a thick description of user experience with smart grid technologies in context.

**Table 1. User representations connected to research methods and connected research fields**

|  |  |  |
| --- | --- | --- |
| User representation(s) | Method(s) | Connected research field(s) |
| Load profiles | Measurement of consumption during field trials | Engineering |
| Preferences | Advanced modeling, Agent based modeling (non-cooperative) | Computing,  Energy planning,  Game theory |
| Responsiveness to prices,  Price elasticities (own or substitution) | Measurement of demand response during field trials with different pricing schemes (ToU, CPR, etc…) | Economics |
| Preferences | Choice modeling | Economics |
| Willingness-to-Pay (stated) for new services or technologies | Quantitative surveys,  Stated preference studies,  Conjoint analysis, | Economics |
| Technical stock,  Number of implemented loads, meters, etc…  Relative investment costs | Archival research,  Budgeting | Economics,  Technology diffusion |
| Responsiveness to information | Measurement of consumption during field trials (various feedback types),  Experiments,  In home audits | Educational research,  ‘Feedback studies’ |
| Descriptions of social practices | In-depth interviews,  Observation of everyday life | Sociology,  Anthropology |
| Use and modification of the socio-technical environment | Design games,  Meta design approach | Design research |
| Use of gaming opportunities (quizzes, goal-setting, etc…) | Monitoring use of web tools | Gamification |
| Responsiveness to social comparison data | Monitoring use of web tools,  Measurement of demand response during field trials | Social computing,  Design research |
| Attitudes,  Identities,  Lifestyles,  Consumer segments, | Quantitative surveys,  In-depth interviews, | Behavioral economics,  Social Psychology,  Anthropology,  Marketing research |
| Participation/ non-participation | Quantitative surveys | Behavioral economics  Social Psychology |
| Awareness, interest or concerns relation to new technologies or services | Quantitative surveys,  Focus groups | Marketing research |

## 4.2 Claims made about users are not always explicit about how actively involved the user is

A main distinction is how actively involved the user is. When users are counted as ‘technical stock’ or as a set of ‘preferences’ they cannot be considered as a dynamic actor. In advanced modeling users do in some sense place bid and shape the outcome but their basic preferences are static. Claims based on these approaches do not draw on any specific user role but the assumptions about user preferences they utilize may still paint a wrong picture of users. In other cases it becomes a bit cloudier. When responding to price alerts or real time feedback users could be said to be in instantaneous active exchange with the system. However, in some projects responses to prices are framed as being dynamic and instantaneous even though they may in practice rely on a set of preferences entered by a user at a previous point in time and only occasionally or rarely revised.

## 4.3 Observed user roles

The large majority of the reviewed projects seem to rest on an understanding of users as somehow responsive to price incentives. We suggest that these efforts draw on a user role that could reasonably be called the **‘Market Actor’**. What is measured is how the user responds to a specific offer. The user is expected to respond to market signals if they fit the value he assigns to the utility he stands to gain or lose. This implies that users can easily valorize the utility a product or service offers them. Some research approaches measure through the demand response in field trials. Other research approaches use specially designed online questionnaires to examine how potential users assign value to different offers. The latter implies that users can act on offers without prior experience with the product or service. The Market Actor user role does not account for other relations between the user and the larger system than those that occur through the market transaction. In some projects it is problematized whether the value gained in the system allow for rebates to be set high enough to motivate users to respond. This partly reflects the main flaw in the Market Actor user role which is that it does not account for or address the cost of the transaction itself. For real users changing behavior is a significant obstacle. If users could easily identify how to move electricity consumption, still get the electricity consuming services done and receive a reward for it, the size of the reward is not important for motivating behavior change. The Market Actor user role does not imply any particular preoccupation on the user side. Hence it is hard to say what kind of utility the user actually is valuing.

[example]

Some projects address another perspective on how the user is positioned in the value creation in the system. We suggest that these efforts are addressing the users through their role as **‘Capital Owners’**. Here users are of interest because they own or may invest in core technologies which are of importance to the function of the larger system. This leads to addressing the relative cost of that investment, the expected payback time or the overall diffusion rate of the technologies. The capital owner user role implies that the users actually use their investment as they are expected. Transaction costs are also an issue with the Capital Owner user role.

[example text box]

The many projects that focus on providing information and evaluating ways of providing information tend to view the user as a **‘Learner’**. That is someone who is interested in receiving information regarding energy consumption and able to make behavioral choices on an informed background. Hence, the purpose of providing the information is to create demand response. Information may be about feedback on actual consumption, prices or advice on how to achieve savings or rebates. The Learner user role implies that learning is gradual and dependent on repetition and delivery of information. The Learner user role does not cover what the user wants to achieve. The main flaw is that the content of the information is not tailored to fit individual users. The lesson is so to speak decided in the curriculum.

[example text box]

Some, mainly small experimental or conceptual studies, treat users as **‘Reflexive Users’** who invest themselves in actively engaging with their home environment or with games that challenge their behavioral patterns. The idea is still to create demand response through information but the experience is augmented by a more open approach to the user. The user can be active by setting goals or by challenging his knowledge in quizzes. Hence, the ‘Reflexive User’ user role implies an element of playfulness in the user. The

[example]

Another group of relatively small studies tries to enable the user as a **‘Community Member’**. The Community Member user role’s main quality is that the user draws on a social context when deciding how to behave. The purpose for the user may differ from seeking social recognition to looking for a social proof. In the studies this is mainly orchestrated through making virtual communities available to users but may also be achieved in other ways e.g. in actual communities. It does not necessarily involve interaction with other community members but may simply be benchmarking the user with peers in a social group.

[example text box]

An opposing perspective can be found in projects that attempt to communicate to established attitudes or deep values in the user. We suggest calling this an **‘Identity Builder’** user role because the user is thought to be activated through his understanding of his identity. The aim is to create demand response or in some cases just to get the user to sign on for a program. The user is assumed to be responsive to non-economic value drivers that fit with his attitudes or values. These can both be hedonistic, altruistic and technical. It is implied that users differ in values. Hence, communication must be designed to fit groups of users that share values.

[example text box]

A handful of projects draw attention to the relative indifference the user has to his electricity consumption. These projects, we suggest, draws on a notion of an **‘everyday practitioner’** user role. The user is a carrier of competences and meaning and a performer of different energy consuming practices in which these elements are integrated with available material elements. The user only integrates new material elements and new ways of doing everyday tasks if they support performance of the practices most important to the user. Hence, it is implied that breaking routines is very hard.

[example text box]

**Table 2. User roles**

|  |  |
| --- | --- |
| User role | Key qualities and behavior |
| Market Actor | The user is maximizing own utility by responding to market signals. The user can easily valorize the utility a product or service offers them. Possibly even without prior experience with the product or service. |
| Capital owner | The user owns or invests in technologies of relevance to the system. |
| Learner | The user is interested in receiving information regarding energy consumption and willing and able to make behavioral choices on an informed background |
| Reflexive user | The user invests himself in actively engaging with his home environment or with games that challenge behavioral patterns. This involves an element of playfulness in the user |
| Community member | The user draws on social context when deciding how to behave. The user can be seeking social recognition or looking for a social proof. |
| Identity builder | The user is responsive to non-economic value propositions/ value drivers. These can both be hedonistic, altruistic and technical |
| Everyday practitioner | The user is a carrier of competences and meaning and a performer of different energy consuming practices in which these elements are integrated with available material elements. The user integrates new material elements and new ways of doing everyday tasks if they support performance of the practices most important to the user. |

To sum up, the observed user roles are quite different in nature. They all have an implicit understanding of which factors that enable change in behavior and hence how users are believed to act.

## 4.3 Projects sometimes use fluffy concepts to address multifaceted user roles

In many projects the user is referred to as a ‘prosumer’. This term is originally meant to describe a user that adds something to the larger system for others to use; one that produces as well as consumes. In this case what is mainly contributed is energy. It is however often indicated that a ‘prosumer’ also contributes with awareness. Geelen et al (2013) use the term ‘co-provider’ to cover what users should be enabled to do to contribute to smart grids.

## 4.4 What the analysis does not answer

Above some projects were used to exemplify how the observed ‘user roles’ are expressed in practice.

We are, however, not trying to connect the perspectives on ‘user roles’ to the type of stakeholders involved in a project or to the type of project in terms of size and funding. Yet subtle differences may arise from the scale implied in the research approach or out of practical or financial restraints on the individual project.

We also do not attempt any precise quantitative estimate of how common the different ‘user roles’ and ‘user representations’ are. In reality larger projects often pursue a number of different ‘user roles’ without actually integrating them at any point. In other cases approaches may differ at an ontological level and yet supplement each other well at the practical level. However, the persuasion power and ability of established knowledge to travel is not equal between approaches. Insights in social aspects are more likely to travel if they can be adopted in algorithms.

# 5. Discussion

As tables 1 and 2 show the research into users and smart grids is actually quite heterogeneous. The different research approaches aim at understanding different aspects of the relation between users and the larger system. Hence they circle around rather specific user roles that are not internally connected. To address how these user roles might complement each other we need to look at some of the assumptions they rest on. We suggest looking at some distinctions made in existing research in behavior and energy consumption and in recent developments in practice theory and transition theory. These are:

1. The included time horizon
2. The included social sphere
3. Theoretical assumptions about behavior
4. Theoretical assumptions about societal change

## 5.1 The included time horizon

The included time horizon varies from real time to changes over a year or over a trial period. The time horizon may not only refer to how long a project runs. Often it has to do with how often exposure to prices, feedback or other data occurs. Too short intervals are reported to create response fatigue. There also seems to be an issue with how long interventions have the attention of users. In most reviews in the field ‘persistence’ is generally reported to be under-researched. Hence, there is an implicit plea for more longitudinal studies.

On the basis of statistical analysis of behavior change in relation to the OPower feedback programme (US) Alcott and Rogers (2012) note that persistence in conservation is an outcome of a) changed habits and b) improvements in the physical stock. This indicates that persistence is secured when the changed behavior is the result of some effort on the user side. Further Ehrhardt-Martinez et al (2010) report that evidence from existing feedback studies show that while most of the energy savings achieved through feedback programs results from changes in behaviors, people who invest tend to save the most energy.

## 5.2 Theoretical assumptions about behavior

Some approaches to behavior change are based on a notion of intentionality whereas other highlight contextuality:

Abrahamse et al (2005) place ‘commitment’, ‘goal setting’, ‘information’, and ‘modeling’ in a group called ‘antecedent interventions’. Here modeling means small fictions showing correct behavior that can be easily mimicked by users. The common trait in these interventions is that they aim at changing ‘behavioral determinants’ (e.g. knowledge) prior to behavior. Interventions that aim a conveying the results of behavior are placed in a group called ‘consequence interventions’ (Abrahamse et al 2005). This encompasses various forms of ‘feedback’ and pricing schemes. Both categories rest on the assumption that behavior is determined by knowledge or attitudes.

This focus on internal resources differs from an ecological perspective that highlights what users draw on to navigate their everyday. This context of available cultural or social guidelines can be both practical and emotion stirring. It may have to do with ‘What is the right thing to do’, ‘how is this done’ or simply ‘what can be done’. These vary in scale from affordances and tightly coordinated spaces to social signifiers and identifiable practices. Some approaches attempt to orchestrate the context, e.g. by using technology to draw a social context into the home, while other draw on it in descriptive research. Hence, context is not to be considered as static or as a precondition. It may also be a change of context introduced by designers. Nyborg & Røpke (2013) stress that user interests develop as users become involved in projects. This challenges methods relying on existing values and awareness in evaluation of smart grid potentials. Shove et al (2012 ) highlight that practices are always situated when they are performed. This means that behavior reproducing practices rests on the elements of material, meaning and competence that are available then and there. In this understanding context is highly important. A lack of available competence or the presence of strongly rooted meaning may challenge new technology and behavior envisioned by designers. Especially if these elements are part of tightly coordinated everyday practices.

At a more practical level Darby (2006) highlights that direct feedback is better at targeting energy consumption that is very tangible (lighting, kettles, etc..) whereas indirect feedback works better when the achieved service is harder to grasp (e.g. heating).

## 5.3 The included social sphere

The approaches showed differences in the social context that was included as relevant. In some approaches virtual communities were included as benchmark for feedback data. Such communities can consist of users involved in the same field trial or they can be modeled on the basis of social segments to provide a social indicator. This approach has some potential pitfalls as users may be satisfied with being in the low end of the best performing or just not in the worst performing group. Evidence from feedback studies has demonstrated this mechanism in energy conservation schemes (Darby 2006). Some field trials, or entire projects, are based in ‘real’ communities like streets, neighborhoods or cities. However these are not conceptualized and incorporated as a social scale for users. The use of small communities like e.g. the Mueller community in the Pecan Street Inc. project is seemingly based on a marketing rationale or an effort to keep initial experiments within an oversee-able scale. Cities are a setting for some projects but this is often more due to alignment with the spatial responsibility of grids or utility coverage. In general there seems to be a lack of conceptualizing geographical context or spatial proximity.

## 5.4 Societal change

Few projects have developed a concept for how smart grids should evolve. There is a tendency to focus at a one of implementation. Gradual diffusion is sometimes addressed but there is rarely any appreciation of more nuanced processes of innovation and experimentation. This is an important fallacy that must be addressed. Shove et al highlight the difference between seeing change as causal or emergent (Shove et al 2012). This has an important lesson for smart grid research in terms of how lessons are transferred from one project or setting to another. There needs to be a critical view on what is passed on as clear universal knowledge and what is handled as historically and culturally specific. It might also be helpful to place considered interventions along a line of relevant scales of social and cultural context in order to address where interventions are targeted and how change is thought to arise.

## 5.5 How can social scientific research address current knowledge gaps about users in smart grids?

Social science may be helpful in defining what ‘effective’ social scales may be in smart grids. What are e.g. the important social spheres for mobilizing social proof or social comparison? In the fields of urban sociology and human geography the urban and regional scale has been a focal point for many years. Actively framing smart grids within this scale may help alleviate that social context has so far mainly been examined in very small field trials and experiments or in virtual communities.

Social science could also work for a conceptual strengthening of large field trials or deployments. Especially in terms of taking into account how innovation appears and how new practices diffuse. Large social experiments may allow new configurations of meaning, material and competence to surface and be recognized as doable practices. This is hard to orchestrate but could be achieved by going for variation in technological set ups and agreements rather than testing the same solution across a large population. Also, learning from ‘failed’ smart grid deployments rather than just highlighting the successes might be a valuable approach.

This being said there is still an issue with establishing how different population segments respond differently to feedback. This is an obvious playground for statistical analysis based on social science categories.

Drifting slightly from a user perspective social science may also support an increased inclusion of technical and scientific communities that work in parallel with the development of smart grids. Answering: What are the potentials for coupling smart grid functions with other efforts aimed at sustainable consumption? Could a wider scope of feedback e.g. be used to enhance participation in audit and retrofit programs?

With this in mind, a renewed social science research agenda could address what roles institutions, culture and even more immediate social contexts play for the inclusion and active participation of end users in smart grids. Of course, it should also take into account the knowledge that has already been produced and help clarify the assumptions about end users and social context that are produced within other participating scientific disciplines. Further, adding a procedural or change perspective to some of the already established evidence may be what is needed to secure smart grid deployment.

# 6. Conclusion

The paper has reported from a survey and analysis of completed and current smart grid projects.

It appears that smart grid research is quite heterogeneous in terms of user roles and representations. Yet, approaches using static attributes to represent users or those relying on intentionality seem to dominate the picture. The attempt to organize the existing research according to user roles and user representations seems to be fruitful but could be refined further. It could very well be complemented by a overview of how concepts travel between projects and scientific communities.

The analysis of differences and gaps in existing research and the recommendations for future social science research is fairly fresh and may certainly be refined further. Some suggestions are offered with some confidence: 1) Social science should work to conceptually strengthen efforts aimed at processes of participation and technology diffusion. 2) Large field trials could benefit from more variation in the mix of technologies and social configurations. More aspects of users of users need to become part of the large field trials because these serve as large scale social experiments.

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# Appendices

## Appendix 1. Table with surveys of smart grid related projects

|  |  |  |  |
| --- | --- | --- | --- |
| Author | Type | Title | Coverage |
| Mulder et al (2012) | Report | Global Inventory and Analysis of Smart Grid Demonstration Projects | Global  (/) |
| Flaim et al (2013) | Journal article | Pilot Paralysis: Why Dynamic Pricing Remains Over-Hyped and Underachieved | US |
| Ehrhardt-Martinez et al (2010) | Report | Advanced Metering Initiatives  and Residential Feedback Programs:  A Meta-Review for Household  Electricity-Saving Opportunities | US and Europe  (57 studies) |
| Foster and Mazur-Stommen (2010) | Report | Results from Recent Real-Time Feedback Studies | US, UK, Ireland  (18 studies) |
| Giordano et al (2013) | Report | Smart Grid projects in Europe:  Lessons learned and current developments    2012 update | European and multinational projects  (257 studies) |