Smart business for smart users?

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S**mart business for smart users?**

A social science agenda for developing smart grids

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Abstract

The promise of smart grids is very attractive. However, it is not yet clear what the future smart grid will look like. Although most researchers acknowledge that users will play a more prominent role in smart grids, there is a lot of uncertainty on this issue. To counter the strong technological bias in smart grid research and literature, we propose that re-

search should focus more on the social and business dimension of smart grid developments. The main elements of such a research agenda are:

- Developing more socially embedded visions on smart grids and the services it will provide;
- A shift in the focus on developing smart grids components and systems towards the services it will deliver
- Development and testing of innovative user-centered business models and ecosystems

More general, on the role of users in smart grids, the main lesson is that user roles should be taken more seriously in relation to smart grids: experts should no longer regard users exclusively and/or simply as potential barriers to smart grid innovation but also as important stakeholders and potential participants in the innovation process.

The smart grid as panacea

The large scale introduction of intermittent low carbon energy sources like wind energy and solar PV at the supply side and the large scale introduction of electric vehicles (EVs) and heat pumps at the demand side are increasingly posing challenges for the existing electricity grids in many countries. Those grids have been designed for a centralised system where the electricity flows from large power plants through the transmission and distribution networks to passive end users or consumers. They have been constructed decades ago and in many cases are near the end of their technological lifetime. The simple solution for these ageing grids is reinforcing the current infrastructure by using cables and lines that can carry much heavier loads. The smart grid is another option for addressing the current electricity system challenges. There is no consensus on what a smart grid is. Wikipedia provides the following definition:

"A smart grid is a modernised electrical grid that uses analog or digital information and communications technology to gather and act on information - such as information about the behaviors of suppliers and consumers - in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity. Electronic power conditioning and control of the production and distribution of electricity are important aspects of the smart grid." (Wikipedia, 2015).

This definition captures beautifully the main promises of smart grids: introducing information and communication technology promises to improve the technological and economic operation of the electricity grid by making it more sustainable and reliable. It also enables a more efficient operation of the grid by reducing losses and at the same time it offers economic advantages for all stakeholders.

The promise of smart grids is so attractive that it has created a hype. Most industrialised nations, including the members of the EU, the USA, and many Asian countries, like China, Japan, South Korea and India, have joined the race to become a leader in the smart grid field. They have set up extensive RD&D programs and are testing smart grids technologies in a large number of pilot projects. The roll-out of smart grids has become one of the spearheads in EU policy. Next to a safe integration of renewables, the ability to accommodate major loads and the creation of new economic activities, the implementation of smarts grids is regarded critical for reaching energy and climate objectives. Another main objective is the empowerment of consumers. It is thus not surprising that in policy circles smart grids are seen to be stimulated at all costs. The investments needed only in the EU are estimated at about 140 billion euro until 2020 (Bowden, 2014).

However, it is not clear at all what these smart grids will look like. Also, not all impacts will be positive. The Wikipedia website continues: “Roll-out of smart grid technology also implies a fundamental re-engineering of the electricity services industry.” (Wikipedia, 2015). The transition to a smart grid will have a major impact on the organisation of the electricity industry, and by implication on all stakeholders in the electricity system. The assumption that there will be only winners is rather naive: there will also be quite a few losers in this. Some actors will disappear completely, others will have to change their operations considerably and new ones will enter the field. Researchers point in particular to the crucial role of users in future smart energy systems. The expectation is that the role of users will change from a passive end user into a more active one (Goulden et al, 2014). In more radical visions, users will become the main players in the future. Although most researchers acknowledge the changing role of users in smart grids, there is a lot of uncertainty on this issue. What are the real advantages of the smart grid for the users and when, why and how would they embrace the new services a smart energy system offers? And who is going to offer those new services and what kind of innovative business models have to be developed? Moreover, smart grids will introduce new potential risks and contested issues as well, including privacy issues, cyber security and data ownership. A larger involvement of users also raises new issues like the potential exclusion of certain groups of users (access to the smart grid) and responsibility for (parts of the) smart energy system. This article will not provide answers to these ques-

tions, but we will elaborate on the kind of research we think is needed to approach these issues more successfully.
The quote on the Wikipedia website continues with the phrase "(...) although typical usage of the term is focused on the technical infrastructure". This refers to the strong technological bias in smart grid research and literature, despite the expected increased role of users and new actors that will be involved. To counter this, we believe research should focus more on the social and business dimension of smart grid developments. We take the following developments as starting points:

- Decentralised or distributed generation of sustainable energy will increase year by year it will become a substantial part of the overall energy supply system; and because of the intermittency and two directional flows, the electricity system is becoming more complex. This is the main argument for adding "intelligence" to grids: more sensing, measuring and monitoring will be introduced. At the demand side, there are two main strategies to deal with these issues: storing electricity and increasing flexibility of demand by introducing demand response or Demand Side Management (DSM). Until recently the emphasis has been on DSM, as there was no business case for local storage, e.g. in batteries, or local system services (Van Vlimmeren, 2010). However, this is changing rapidly due to progress in battery technology (see the recent announcement of Tesla's Powerwall), but also because of changes in policy. Reduction of feed-in tariffs and other support schemes for solar PV will encourage local consumption of locally generated electricity (self-consumption).
- Linked to the increasing application of IT devices and software, these developments will trigger major changes in local energy systems in houses and buildings. A new local energy system will emerge, consisting of a smart meter, ICT, display, a home energy management system and several smart appliances (or home automation). This new system "behind the meter" will have a huge but yet unknown impact on daily routines and practices of users.
- For a major part of the 20th century the role of the government in the energy domain increased but under the spell of neoliberalism in the

1980s and 1990s the government retreated and increasingly relied on the market and market based instruments. The current system is still struggling with these changes. The energy system is still in transition, although not necessarily in the direction of a more sustainable one (Verbong & Geels, 2007).

- Changing relations between state, market and civil society are especially apparent in the field of electricity. In the Netherlands this dynamic has been called the “energieke samenleving”[1], implying that the relations between state, market and civil society are changing. Indicative for this development in the energy sector is the appearance and diffusion of energy cooperatives and other local and regional energy initiatives in many countries (Seyfang, Park et al, 2013; Yildiz, Rommel et al, 2015). These local energy cooperatives (or other organisational forms) are platforms in which citizens cooperate in working towards a more self-sustainable, renewable and localised energy system.
- The combination of these developments is creating a difficult situation for the incumbents. It is threatening their main assets: large fossil fuel-fired power plants. Because of the way the electricity market is organised, these power plants are increasingly becoming uneconomic. Some utilities like E.ON announced a dramatic change in strategy and a focus on renewables and service (E.ON, 2014). This results in interesting new hybrid business models that incorporate both mainstream and niche market players (Huijben & Verbong, 2013).

With users no longer perceived as passive consumers but as active participants, their role in smart grid innovation, either individually or collectively, is of key interest. Following this user centered perspective we identify the following research fields as being of particular importance when researching current dynamics of the changing electricity landscape. First we will address the use of new approaches to develop smart grids visions

[1] Literally this translates as ‘the energetic society’

that include the social and user dimension. In the next section, we will focus on energy consuming social practices, followed by the emerging field of business models studies. Which - we will argue - needs to include a more explicit focus on user centered business models. In the final section we will summarise our finding in an agenda for socially and business oriented smart grids research: smart business for smart users.

Envisioning the smart grid

As indicated, our current energy system is changing rapidly. The liberalisation of energy markets, the process of European (dis)integration, increasing geopolitical instability and the issue of climate change are threatening the dominant mode of generation and distribution. Distributed generation, increasingly by renewable energy sources like wind energy and solar, also are putting the traditional system of large scale power plants and HV grids under pressure. The fast diffusion of the application of IT in the energy domain contributes to the uncertainty and raises questions about the future development of the energy system.
The traditional approach to deal with this uncertainty has been technological forecasting and roadmapping. These approaches are characterised by a rather linear extrapolation of on-going developments or, as in roadmapping, the steps needed to reach the targets set by the stakeholders involved. The first energy crisis in the 70s demonstrated the limited usefulness of these approaches. Royal Dutch Shell used scenarios as a method for dealing with the uncertainty. The core idea of scenario planning is to explore a set of different scenarios based on a few main driving forces. This enabled Shell to develop robust strategies that would work in different scenarios, in different circumstances. These scenarios and the scenario methodology, developed by Shell and other organisations, have had a large impact on future studies, but they focus predominantly on the supply side of the energy system (e.g. availability of resources, prices of resources, technological innovations).

The increasing focus on sustainability introduced a new normative approach of exploring the future. A sustainable future becomes the starting point and via a process of backcasting the necessary (policy) measures can be identified. The problem with backcasting however is that it remains very difficult to determine what a sustainable future will look like. The normative approach leads to often unrealistic or one-sided assumptions on the future; moreover, most backcasting scenarios also have a strong technological bias. The focus has shifted now to include the social dimension, as in socio-technical scenarios and the process of framing and envisioning the future. This challenge has been taken up by Shell in the New Lens scenarios, published in 2014, but more on a global scale, e.g. by envisioning a strong role for the government in its Mountain scenario. (Shell, 2014).

Visions and scenarios can be very powerful, in particular if these can be visualised in one or few persuasive images. The role of visions (and expectations) has been studied by STS scholars, in particular by the 'Sociology of expectations'(Van Lente, 1994; others); other bodies of knowledge include the Leitbild perspective and Transition Management. These literatures point to the performative nature of visions. Expectations (and visions) *act*, that is, visions not only describe a future situation, but by its articulation and acceptance they become a factor in the development (Van Lente, 1993; Dignum, 2013).

Wiek & Iwaniec (2014) developed quality criteria for visions and visioning for the sustainability domain. They distinguish between the normative quality (visionary and sustainable), transformational quality (relevant, nuanced, motivational, shared) and construct quality (systemic, coherent, plausible, tangible) (Wiek & Iwaniec, p. 501). They also stress the importance of the design process and provide some guidelines for this process, including the use of creativity techniques, visualisation techniques and participatory settings. These criteria and guidelines are useful for developing more user centered smart grid visions.

The smart grid concept, as presented in the literature, covers very different visions and scenarios. These range from a slightly improved version of the current grid to a self-healing Energy Internet, from a large European

Super Grid, to a collection of micro grids (or DisGenMiGrids, Wolsink, 2012). What they have in common is that the smart grid is presented as the solution for all problems and as a great economic opportunity for leading nations and industries. From our perspective, these smart grid visions are technological or techno-economic visions. They focus too much on technological fixes and pay little attention to social dynamics and contexts, relating to beliefs, decisions, struggles and interactions between various actors and social groups (Verbong & Geels, 2010). If there is attention for dynamics of change, the vision (or scenario) emphasises the impact of factors like energy prices, investments, and balancing supply and demand. Although these economic mechanisms are important, most visions and scenarios pay hardly any attention to cultural aspects, regulatory paradigms and user behavior. Experts from government agencies or network operators often acknowledge that users will play a different, more active role in the future energy system, but the roles they propose reflect the ideas of the current players in the energy system and these do not match with the new emerging reality. They claim e.g. that the perception of a potential outage is more important than the actual time this occurs or argue for that an overrule button is necessary to give people the feeling of control (Verbong et al, 2013, p.122).

To counter this supply system and technology push bias, the emphasis has to shift to a more socially embedded vision. In such a vision the *function* of the energy system is taken as a focal starting point, and the question *what do we need energy for?* becomes central. This argument has been made by Walker & Cass (2007) in their paper on the different modes of renewable energy in the UK. The authors concluded that “the social organisation of a local energy system is a combination of different interacting arrangements and relations between actors and institutions”. For the analysis, they use four sets of questions. These refer to:

- *Function and service of the system,* in particular what is the generated energy being used for in terms of the services it provides, like comfort, warmth, visibility, mobility etc.? Also, who uses these services?

- *Ownership and return*: this is about who owns the system and how this ownership is organised: privately, publicly, collectively? The ownership is relevant for the allocation of costs and benefits.
- *Management and operation*: who manages, controls and maintains the system and how is this organised?
- *Infrastructure and networking*: this is about the relation to larger networks (Walker & Cass, 2007).

The third question obviously is relevant for smart grid business models. 'Who manages and controls' is important for cooperation and/or compliance of users. The fourth question provides the context for the ecosystem setup (see below). We will first focus on the first two questions. By focusing on the services (i.e. the function) of the energy system, Walker and Cass make a very important point. Although the energy system is vital for modern society, for most users the only relevant aspect is that they can do what they want to do. If these activities need energy, the energy system has to deliver. Only in case of malfunctioning do users become aware of the system. In most European countries, the reliability of the system is very high. In some emerging economies, in particular in India, grid unreliability is a real problem and other options are being employed, ranging from installing backup generators to local off grids systems. The fact that the energy system primarily *enables* other functions has an important consequence for envisioning a smart grid. Instead of the energy system itself, its function(s) should be the starting point for vision (and) analysis, and with this the services it delivers for cooking, comfort, cleaning, communication, mobility, entertainment etc. Thus, a focus on social practices that need energy (Shove, 2014), rather than on the energy system, offers a more fruitful view onto the challenges and opportunities of a changing electricity landscape.

The second question related to ownership and return is becoming more prominent as well. In the traditional mode of operation the energy system provided the energy and the users paid a bill. As consumers are turning into prosumers by installing a PV system on their roof, or as citizens are becoming active in local energy cooperatives, the issue of how to organise the energy system is becoming increasingly relevant. In fact, the participation in energy generation or collective energy initiatives can be regarded as a new social practice, an indication of seizing new opportunities that technology offers and of new societal dynamics. As a result new pattern of and actors in value creation and appropriation emerge. (Adner & Kapoor, 2010; Huijben & Verbong, 2013; Zott et al, 2011).

Social practices

The solution that smart grid technology provides rests heavily on DSM, technology which allows conveniently shaping the demand patterns of households without impacting quality of life. Smart grid promises come with an implied change of the consumer into prosumers or energy managers. This promise is contested because, as we have concluded above, electricity is consumed for a reason: it is essential for our daily practices, which are bound up in routines and social relations.

Practice theories offer a promising basis for a programme of research on patterns of consumption, because its focus is on the mundane activities of everyday life (Warde, 2014). By emphasising routines and practical consciousness over actions and deliberation, it offers an alternative to dominant models for consumption behavior. Research on energy consumption and the policies built and aimed on this have generally been dominated by one of two interpretations of human behavior and decision making. Reckwitz (2002) clearly positioned these accounts (in extremis) as the voluntarist *homo economicus* who makes conscious, rational and weighed decisions to reach maximum individual benefit, and the functionalist *homo sociologicus* who is guided by norms, rules and regulations solidified in political and social institutions. Neither account is wrong, and both make sense to a degree, but neither one alone can give a satisfying explanation of human action. Giddens' (1984) concept of structuration is often cited as a way out of this dichotomy. By focusing on practices itself, the opposing branches of structure-centric functionalism and actor-centric voluntarism are brought together.

For the research on smart grids the question is how a social practice approach can be used to study the development and implementation of smart grids. The concept of elements of practice provides a conceptual lens to identify building blocks of practice (Schatzki, 1996; Shove & Pantzar, 2005; Warde, 2005; Gram-Hanssen, 2010). Three elements of social practice can be distinguished: stuff, skills and meanings. Stuff or material refers to all material elements applied in the practice, including objects, infrastructure and the body. Skills or competences are learned through doing and refer to the routines of bodily and mental know-how to perform the practice, the ability to appreciate objects and situations and applying knowledge about what is normal or appropriate. Meaning or images entail the reasons to engage in a practice, the reasons about what it is for and what is a good outcome, which are socially shared ideas.

Through time the individual performances can change as elements change through new technology, new understandings or new goals. As links between elements are made, renewed, shifted and broken, practices emerge, change and fade out (Shove, Pantzar and Watson 2012). When individual performances change in some way, this feeds back into the collective understanding of the practice. This somewhat abstract structuring mechanism is what makes practices social, even though they might be performed in private. When performing a practice, individuals integrate elements that they take from their interaction with society: the norms, values and expectations that guide their action, technologies and data, and competences they've learned in society.

Within these elements lies a key to understanding consumption from a practice perspective; if any practice is to change to be more sustainable, the elements that it is made up of will have to change. Social and technological innovations act as potential new elements, which could become part of existing consuming practices. Smart grid innovations could also lead to the emergence of new practices of energy monitoring, storage and management, which we call emerging e-practices (Naus et al, 2014). Smart technology will only realise its promised benefits if it becomes part of practices, be it emerging e-practice through which energy is generated or managed, or in 'smarter' energy consuming practices. There is uncertainty however on how these consuming practices will evolve with the social and technological innovations emerging within a smart energy system. Supposedly smart technologies might not provide the user with meaningful benefits, for example because the financial gain is small or because energy itself doesn't capture the user interest. Existing patterns of consuming practices might persist despite them not corresponding with the profile of self-supplied electricity and the idea of the responsible energy managing householder. The promise of smart grid technology might not be realised if it does not become part of daily practices. By focusing on domestic practices we claim that it is possible to assess more realistically the entry and use of energy-related social and technological innovations in the household, which could enable a radical transformation of the local energy system. This means that both the existing patterns of consuming practices as well as the potentially emerging e-practices connected with the new technology have to be studied.

User-centered business models

The focus on social practices will help to get away from a technology push approach to smart grids. The provision and consumption of energy is usually not a goal unto itself: the energy system rather enables all kind of social practices that need energy. In modern society this includes almost all social practices, ranging from the energy needed to provide comfort (heating and cooling in houses) to almost all communication and entertainment practices. The ubiquitous presence and use of smartphones, tablets and other IT based devices is only possible because of the existence of a highly reliable grid. One of the promises of the smart grid, next to improving the system (reliability, renewable energy) and reducing electricity bills, is that it offers great opportunities for economic development: companies can use the smart grid infrastructure to develop new services for users (Giordano & Fulli, 2012). However, despite some experiments and pilots, there is still much uncertainty about what kind of services will be useful and accepted by users as well as how to relate to existing user needs and social practices.

Research on new services focuses on the development of new business models that can provide these services to the end user. Business models are considered to be vehicles for bringing new technologies like renewables to the market (Boons & Lüdeke-Freund, 2013; Zott et al, 2011). Smart design of business models and including new services can help to overcome investment barriers to end users. For example, providing finance to house owners with low income spurred solar PV markets in the US (Drury et al, 2012). Additionally, in the Netherlands collective buying of solar panels enabled easy investment to the end user who did not have to take care of selection of a supplier or installation and maintenance since this was arranged by a central party (Huijben and Verbong, 2013). Business models are also considered to be a source of innovation and competitive advantage for a company (Zott et al., 2011). This in particular applies to (potentially) radical innovations; in this case, there usually is no proper exemplar and new business models have to be developed and tested in practice (Huijben and Verbong, 2013). By performing business model experiments, action is taken to find new information about 'latent possibilitiess' that were previously unknown rather than simply analysing the environment (Chesbrough, 2010, p 361). On the other hand business models can enact their context as well (Osterwalder and Pigneur, 2010). Business model mapping can support the design of such experiments by analysing current and designing future business models (Chesbrough, 2010). Another important aspect of innovations in complex systems like the smart grid is that business models need to cross individual focal firm boundaries (Zott et al, 2011). In this case, value is created in a network of actors rather than by an individual firm alone (Huijben and Verbong, 2013; Zott et al, 2011). This is implied in the notion of a business *ecosystem* (Adner & Kapoor, 2010).

In an ecosystem a network of suppliers, lead producers, but also customers and other stakeholders (co-)produce goods and services that are valued by the customers. The lead producer usually is ecosystem leader. Lead producers often are innovative companies. However, if we translate this to the smart grid research, it becomes obvious that at the current state of smart grid development it is not clear who the ecosystem leader is or will be. The obvious option would be the utilities. But in the Netherlands the large utilities are hardly active in the smart grid field, in fact a substantial part of their assets are being threatened by the rapid growth of renewables and cheap coal. For Germany this includes the forced closure of nuclear power plants. Several of the largest utilities in Europe are under heavy pressure. Their challenge is to survive the energy transition (Van Berlo, 2014). German utility E.ON has drawn the conclusion that the answer is to focus on renewables and offering energy services to their clients. New entrants also have adopted this strategy: new Dutch energy supplier Greenchoice offers its customers specific payment schemes to enable them to participate in renewable energy projects (Huijben and Verbong, 2013). Another candidate as lead actor are the distribution network operators (DNOs). DNOs in the Netherlands, like Alliander, Enexis, Stedin, have been heavily involved in smart grid pilots. It is fairly obvious why smart grids are relevant for these companies, but DNOs have different interests in developing smart grids, as their task focuses on maintaining the balance in the grid and the reliability of the system. If DNO's would be the lead actor in the development of smart grids, the smart grid business model would look completely different from a utility led smart grid. For example, preventing the occurrence of peak loads will increase the life span of key components of the grid, like transformer stations, and delay the need to invest.

Another, interesting option are entrants from sectors outside of the energy domain. The most obvious candidate is the IT sector, as this sector has to supply both hardware and software for making the grid smart. In fact, there is a clear trend that IT companies are getting involved, for example in the case of online crowd funding (Vasileiadou et al, 2015). But again, the challenge is not so much the technological part of the system, but much more the kind of services that can be provided. Discussion has mainly focused on saving energy by giving feedback on energy consumption or reducing electricity bills by using favorable tariff schemes. Both approaches have their shortcomings. As we have been arguing, the starting point should be the provision of services (Verbong et al, 2013). Companies should develop business models that focus on the social practices that need electricity and the management of electricity itself. Framed differently: we need business models that meet the demands of the user. The limited success of energy services that are available in the market, e.g. to increase energy efficiency, follow from a mismatch between existing social practices and the service offered (Hargreaves, Longhurst, & Seyfang, 2013). To conclude, there is a need for user-centered business model and ecosystem design with a strong focus on learning and experimentation. Such models should be co-produced by users and suppliers. This brings us to the role of users in sustainable innovations, including smart grids.

The user as innovator

Users can - and probably will - play a much more active role in smart grid innovations than has been the case so far. Users are not only purchasers and consumers of a technology but they can be involved in various degrees in the production process (e.g. through providing input to designers) or even act as a co-producer and add value themselves (Habich et al, 2015). In innovation studies literature, users have traditionally been conceptualised as buyers/consumers, but over the last decades, we observe a shift towards the study of the so-called ‘democratisation’ of innovation (Von Hippel, 2005), meaning that the field acknowledges that (and researches how) users can play roles such as (co-)producers of innovations, as well. This trend is supported by improvements in computer and communications technology that enable users to develop their own new products and services. This enabling role of IT for users to engage in innovative activities obviously extends to the smart grid field as well.

So in what ways can citizens, as users or non-users of an innovation, influence its development? A scan of innovation studies literature reveals many different roles, and although the heterogeneity of frameworks and theories in the field renders it impossible to come to overarching, integrative statements about the precise *mechanisms* of user involvement, we can at least attempt to create a *typology* of roles by juxtaposing them according to two dichotomies (see Figure 1). The first dichotomy is that of constraining or barrier-like user roles versus enabling or empowering ones: users can either help a transition to smart grids or block it. The second dichotomy is that of passive versus active roles (i.e. is the positive or negative influence the result of strategic behavior or not?).

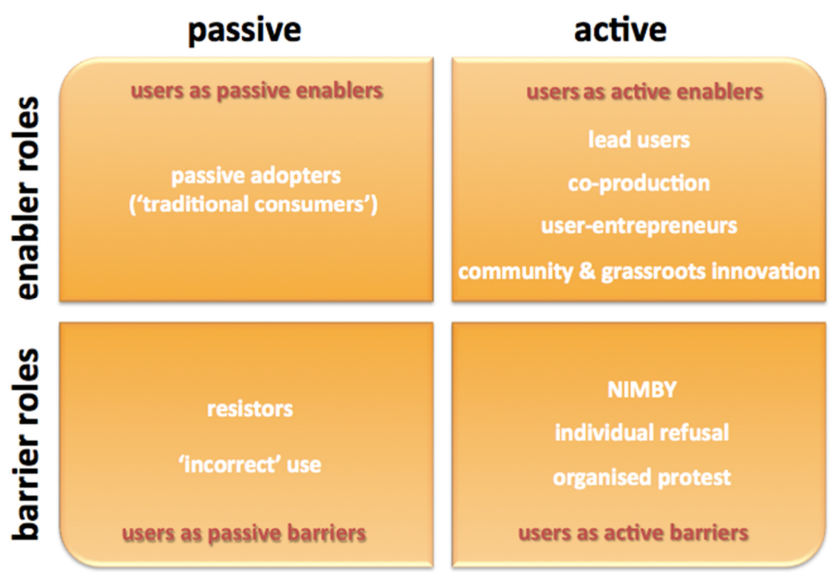

Figure 1: A typology of user roles in sustainable innovation

Below, we will elaborate on these quadrants. As an aside, it is interesting to note that within all four quadrants, individual users roles are present (e.g. investigating the psychological, cultural, physiological characteristics that render them more or less inclined to opt in or out), as well as collective ones[2] (e.g. adopt a more sociological perspective in which various group dynamics play a role).

Passive barrier roles

In the lower left quadrant, we find various passive barrier roles: e.g. not participating in using the available options of the smart energy system due to individual preferences and/or collective practices, or 'incorrect' use due to lack of knowledge. Individuals are subsumed into adopter categories (early adopters, early majority, late majority and laggards) that aim to explain non-adoption. Often, non-users roles are simply seen as resistors to an innovation: rejecters, excluded and expelled users are largely ignored (Wyatt, 2014). When smart grid literature talks about users, it predominantly talks about this quadrant, and 'solutions' often take the form of educating (or 'domesticating') users to move them to the upper left quadrant.

Passive enabler roles

In that upper left quadrant, we find the 'traditional consumer': a passive adopter of an innovation (in this case: a participant in smart energy systems).

Active barrier roles

But more active user-barriers to implementation exist, as well. We find these active barrier-roles in the lower right quadrant: active resistance by individual households to a smart grid innovation (e.g. refusing to install smart meters or to give access to data) and the so-called NIMBY ('Not In My Back Yard')-phenomenon, as well as more collective roles that can range from large-scale social movements actively resisting innovations through organised protests and political pressure (e.g. against nuclear

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[2] One might view 'individual' versus 'collective' roles as a third dichotomy but we thought it wise not to formally introduce it as a third dimension to our tentative typology for reasons of clarity.

power (Geels and Verhees, 2011) to more local, yet highly organised resistance (Höffken, 2012).

Active enabler roles

Active enabler roles reside in the upper right quadrant. For example, users can become so-called 'lead users' (Von Hippel, 1976) that act as a key sources of information and ideas that lead to innovations which are then marketed by firms (e.g. households actively engaging in smart grid projects and providing feedback to suppliers, DNOs and utilities). Other active enabling roles are e.g. individual households as small decentralised renewable energy producers (e.g. through smart grid-connected solar PV and/or energy storage in EV batteries); or even 'user entrepreneurs' who convert sustainable solutions to a problem they experience into a business. In addition, *collective* user roles that actively enable sustainable innovation are captured by concepts such as 'collaborative consumption' (e.g. co-housing, car sharing), 'cloud-based' and 'peer-to-peer' business models in the IT domain, and the 'collective buying power'-based business model: autonomous associations of users who cooperate for mutual benefit (e.g. collective purchasing of PV panels to bring down prices; Huijben and Verbong, 2013). Others models for collective enabling of sustainable innovation include 'crowdfunding' (wherein collective users are a source of capital for technological innovations: these collective user investors thus influence the innovation process in a much more active way than simply buying innovations; Vasileiadou et al., 2015)), and 'cooperatives' (groups of users that do not own their own land or roofs but collectively rent plots or roof space and install relatively large capacities of collectively purchased wind turbines or solar panels and in doing so, effectively become small, collective energy producers (Asmus, 2008; Dewald and Truffer, 2011; Huijben and Verbong, 2013)). Finally, 'community innovation' is worth mentioning is this respect: groups of users collective users that act as initiators, designers and maintainers of technological projects in their own locality (e.g. street, neighborhood, village), as well as 'grassroots innovation' (Seyfang & Smith, 2007), in which social movement organisations (a form of collective users) actively produce sustainable innovations for such niche markets but, in doing so, expand beyond their locality and form the seeds of mainstream solutions. The numerous Local Energy Cooperatives are a prime example of such collective engagement.

And these are just the roles that ‘actual’ users can play. We have not yet even addressed the so-called ‘socially constructed’ or ‘projected user’(a fictitious individual user whose supposed needs producers target); the ‘configured user’ (a user who is ‘trained’ in his/her interaction with an innovation by the‘script’ embedded in the smart grid technology (Akrich, 1992), (Woolgar, 1991)); or ‘mediated’ or ‘represented’ users (users that are spoken for by organisations that claim to represent user groups: collectives that mediate between real users and producers).

As stated earlier, all these possible user roles have their own complex social dynamics and generative mechanisms. Research exists on all of these roles: individual or collective, constraining or enabling, passive or active. It is quite impossible to review these mechanisms here comprehensively: instead, we have tried to paint a picture of the plethora of possible roles and the very different consequences they may have for a transition to smart grids. The main lesson here is that user roles should be taken more seriously in relation to smart grids: experts should no longer regard users exclusively and/or simply as potential barriers to smart grid innovation but also as important stakeholders and potential participants in the innovation process. Our suggestion is to take stock of users roles across the whole matrix of Figure 1 and not just the left-hand quadrant: don’t forget that your users can be, for better or worse, at least as smart as your grids!

Smart business for smart users: a research agenda

This article has addressed some of the main problems for smart grid research. Due to the increasing number of options technology offers, the future smart energy system will differ radically from the current one, re-

sulting in large uncertainty on almost all dimensions of a future smart grid. In particular this applies to the role of users in future smart energy systems. We simply do not know how users will adopt, adapt and co-create the part of the future energy systems that is relevant not only for the users but certainly also for all other stakeholders involved. What we do know is that a technology-dominated approach will very likely fail or at least will not produce the intended results. That is why we propose a different agenda for research on smart grids.
To summarise: the main elements of a social science research agenda are:

- Developing more socially embedded visions on smart grids and the services it will provide; this should not be left to the 'experts', but include all relevant actors
- A shift in the focus on developing smart grids components and systems towards the services it will deliver, taking energy consuming practices as a focal starting point
- Development and testing of innovative user-centered business models and ecosystems; there are pilot projects that experiment with new business models, but often still too much technology driven
- More general more attention to the innovative role users can have in smart grid development, and broader in sustainable innovations

Although we did not address this in this article, smart grids are a phenomenon that is not confined to Western societies in the global North. Studying users in smart grid dynamics beyond the Western confines will therefore enable a wealth of information that will enrich the theoretical and practical vocabulary of current research and contribute to a more nuanced understanding regarding the what, why and how of users and smart grids.

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