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The social dimension of Smart Grids

Consumer, community, society

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1. INTRODUCTION

Growing concerns over climate change, security of power supply and market competitiveness are challenging the current power system operation and architecture, with the resulting need to integrate increasing shares of renewable and dispersed energy resources (Gangale et al., 2013). Some of these renewable energy sources will be installed directly at the premises of the end consumers (e.g. photovoltaic systems), transforming their role to prosumers (producers-consumers).

The present power system infrastructure was not designed to meet the needs of a restructured electricity market, to face the increasing demands of a digital society and to account for an increasing use of renewable resources. The current grid is one way channel where balancing of supply and demand in real time is accomplished by adjustments on the supply side. Until recently, customer demand was not subject to control with virtually no means or incentives for load to play an active role (Sioshansi, 2011). The modernization of the grid, with power and data flowing in both directions, to and from the prosumers, will demand and enable new market structures, new services, and new social processes.

In summary, the era of renewable energy, decentralized energy sources and smart grid technologies will empower all prosumers, from households to small and medium sized enterprises, as well as larger companies, to integrate their consumption and production of energy in networks that would function more like ecosystems than markets. This situation will undoubtedly challenge conventional power generated by centralised power and unidirectionally distributed by utility companies (Rifkin, 2010). Current consumers of energy will be able to act as energy generators through distributed generation from solar PV and waste heat recovery. Consumers would also contribute to a smoother operation of the electricity system through demand response and energy storage. Enabling and encouraging technologies and behaviour that optimise the entire energy system, rather than only individual parts of it, can unlock tremendous economic benefits (IEA, 2012).

However the development of the smart grid, described as an upgraded electricity network enabling two-way information and power exchange between suppliers and consumers through pervasive incorporation of intelligent communication and management systems (Giordano et al., 2011), is still surrounded by technological, social, financial and environmental uncertainties (Zio and Aven, 2011) as well as risk, particularly in relation to social and economic factors (Darby, 2012). The success of the smart grid will critically depend on the overall functioning of the energy system as a socio-economic organization, not just on individual technologies.

As a consequence, the most important challenge for policy makers over the next decade will likely be the shift away from a supply-driven perspective, to one that recognizes the need for the integration of the different dimensions and actors of the energy systems.

Several recent studies recognize the social dimension of smart grids, that is to say the inclusion of consumer, community and society, as central to the successful deployment of the smart electricity grid. In this context, the aim of the present report is to shed light on the different components of the social dimension of smart grid, from the perspective of the consumer, community and society at large, and to highlight and discuss the main challenges that surround it. We base our discussion on the result of the analysis of the smart grid projects inventory developed by JRC (Giordano et al. 2011; Giordano et al. 2013).

The report is organized as follows: in section 1 we present the role of the consumer in the future electricity system and after discussing the findings of the analysis of the JRC smart grid projects database, we present the challenges ahead, namely, understanding, engaging and protecting the consumer. In section 2 we present and discuss the increasing important role that communities will play in the success of smart grids. Finally in section 3 we discuss the social implications of smart grids. We conclude discussing the needs for further multidisciplinary research.

2. THE CONSUMER

With the smart electricity grid, the traditional paradigm of passive distribution and one way communication and flow between suppliers and consumers is going to be replaced by a new paradigm of active distribution that can dramatically change the role of the consumer. The smart electricity grid thanks to a pervasive incorporation of information and communication technologies will enable bidirectional communication and power exchange between suppliers and consumers, transforming the traditionally passive end-users into active players. It is important, at this early stage, to understand and involve consumers in order for them to successfully assume their new role as active participants in the electric power system. As most energy services will be equally produced and consumed by all actors, it is essential for energy providers to develop closer relationship to their consumers during the new service development process in order to ensure good performance of new services (Gangale et al, 2013). Therefore consumers, their daily routines and the social context in which they operate, should be more central for the grids utilities, where the focus is still mainly on technological issues and economic incentives (Wolsink, 2012; Verbong et al., 2013; Geelen et al., 2013). Many studies have been recently published where consumers have been involved in interviews and studies to assess their perceptions, understanding and willingness to pay for the development of smart grids technologies (Diaz-Rainey et al, 2008; Ngar-yin Mah et al., 2012a; Krishnamurti et al, 2012). These studies acknowledge a consumer positive attitude towards smart grid technologies; however, they also recognize the need to address erroneous beliefs and misconceptions that still exist about these new technologies and to strive for trust, transparency and feedback to gain consumer involvement and acceptance.

In particular, the role and uncertainties linked to consumers' involvement in sustainable consumption are also acknowledged by the EC Task Force for Smart Grids (EC TFSG, 210): "the engagement and education of the consumer is a key task in the process as there will be fundamental changes to the energy retail market. To deliver the wider goals of energy efficiency and security of supply there will need to be a significant change in the nature of customers' energy consumption (…). A lack of consumer confidence or choice in the new systems will result in a failure to capture all of the potential benefits of Smart Meters and Smart Grids". Moreover, the European communication on smart grids (European Commission, 2011) further recognizes the importance of consumer awareness and underlines how "developing Smart Grids in a competitive retail market should encourage *consumers to change behaviour*, become more *active* and *adap*t to new 'smart' energy consumption patterns". However, the Communication also recognizes the uncertainty linked to this new technology: "Neither is there clarity on how to integrate the complex Smart Grids systems, how to choose cost-effective technologies, which technical standards should apply to Smart Grids in the future, and *whether consumers will embrace the new technology*"(European Commission, 2011).

The Council of European Energy Regulators (CEER) discussion paper "*2020 vision for Europe's energy customers"* (CEER, 2012) also acknowledges the low level of customer engagement with energy market and underlines how decisions made today on rules and conditions in the energy markets will affect how market operates and therefore will have an impact on customers for years to come. Therefore *understanding what energy customers want and how they behave* is fundamental to design Europe's energy markets.

As argued by some authors, the only aspects of the smart grid that can be truly smart are the people within it (Honebein et al., 2011). In other words, consumer action is the fundamental driver. Therefore, if we do understand the consumers at these early stages, smart grid initiatives risk failing to realize their full potential (Honebein et al., 2011). This is why many argue in favour of increasing focus on consumers and their daily routines, while the smart grid community currently still focuses mainly on technological issues and economic incentives (Verbong., 2013). Hence, as one cannot wait until the full implementation of the smart grid, observing at an early stage consumers in their social context (e.g. household or community) and including them in the development process, would be fundamental for the future electric power system to deliver the expected goals.

Jackson (2005) argues that sustainable consumption and consumer behaviour are key issues to the impact that society has on the environment. However, he acknowledges the challenges and difficulties of changing consumption behaviours and motivating consumers. Consumers are mostly locked into unsustainable consumption patterns influenced by routines, social norms and expectations, as well as incentive structures, institutional barriers and restricted choice. Jackson (2005) argues that consumers are guided as much by social norms and the behaviour and opinions of people around them as by personal choice. This is an acknowledgement of the complexity associated with negotiating, engaging and motivating pro-environmental consumer behaviours and with the development of appropriate engagement strategies.

In particular, studies in the psychology of energy use show that the most effective and successful information strategies that engage the consumer in energy conservation are those that include individualised social marketing approaches, which provide information that is tailored to the needs and wants of individual segments of consumers (Steg, 2008) and strategies that provide information about the behaviour of others (Abrahamse et al., 2005; Allcott, 2011). Consumer engagement in sustainable technology is influenced by attitude, social norms, perceived behavioural control and personal norm. In particular, attitudes can be influenced by such important factors as confidence, trust and distributive fairness (Huijts et al., 2012).

In the following sections we will first present approaches and strategies to consumer engagement adopted by European smart grid projects. The discussion is based on the result of the analysis of European smart grid projects included in the JRC 2012 smart grid inventory (Giordano et al., 2013). Then, we will present and discuss the future challenges of understanding, engaging and protecting the consumer.

2.1 Insight from European smart grid project

The aim of the present section is to present the current developments in consumer engagement strategies in smart grid projects in Europe. The results are based on the analysis of the JRC database of Smart Grid projects in Europe - update 2012 - (Giordano et al., 2011; Giordano et al., 2013). Our results include only those Smart Grid projects that have provided information on the section "consumer engagement" of our online survey[1]. We exclude all the other projects, though these may include projects with consumer participation. Out of the **total 281 Smart grid projects** (R&D and demonstration), a **total of 65** answered the section on consumer engagement. The analysis shows that the number of consumer engagement projects has been increasing since 2005 as shown in Figure 1, though the number is still limited in comparison to the total number of smart grid projects available in the database.

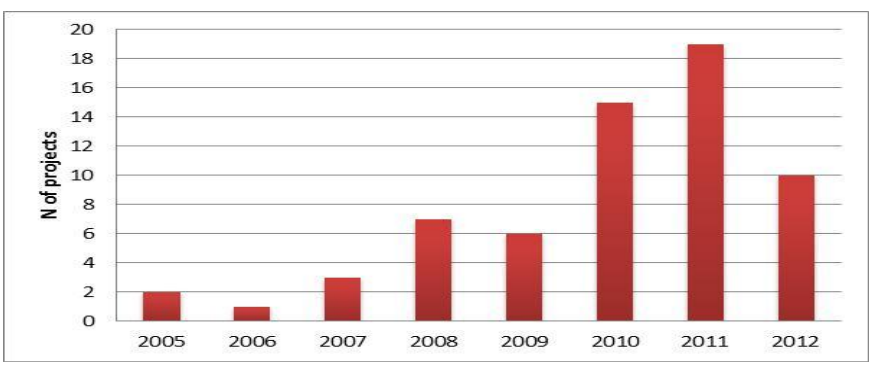

Figure 1: Number of projects with focus on consumer engagement

[1] http://ses.jrc.ec.europa.eu/survey-collection-european-smart-grid-projects

In particular, many projects started in 2011 and 2012. Data for 2012 include only projects that were sent before July 2012. Consumer participation in the projects is still limited in number, with typically up to 2000 consumers involved.

Most of the collected projects indicate a focus on the residential sector. The predominance of the residential sector can be explained by the need for energy providers to target household consumers. Indeed, residential consumers represent a huge potential for energy savings that energy providers can tap into.

2.1.1 Leading organizations

Distribution System Operators (DSOs), challenged by the need to integrate increasing shares of renewable and distributed energy sources while ensuring security of system supply, are inherently interested in enhancing flexibility through energy efficiency and dynamic pricing so as to enable consumers responsiveness. Indeed, the survey shows that DSOs have started developing projects aimed at getting to know the consumers' preferences and behaviour and the impact of their choices on system's operators (Gangale et al., 2013). DSOs, as Figure 2 shows, are acting as one of the key enablers for consumer's integration in the distribution network. Most of the consumer engagement projects in our survey are led by DSOs (43%). Figure 2 also indicates an increasing interest in consumer engagement projects of service provider and energy companies that will have an important role to play in the future.

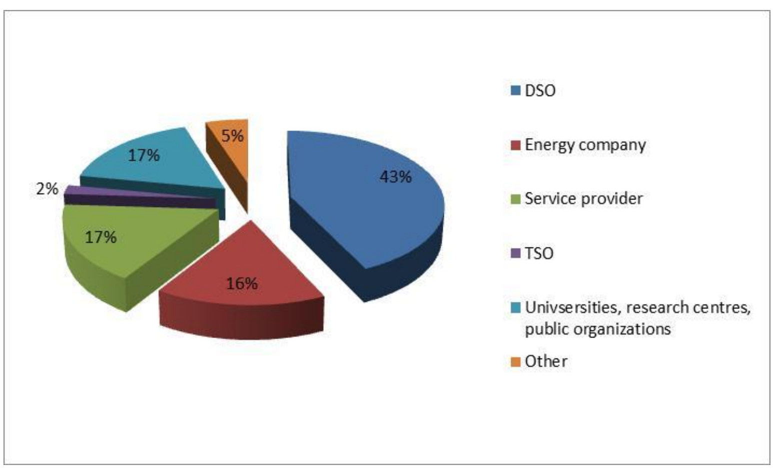

Figure 2: Leading organization in consumer engagement projects

The DSOs, challenged to operate the distribution networks in presence of large amount of variable power generation, appear as one of the leading organisations in recognizing the importance of electricity consumer engagement and enabling consumers' active participation in the distribution network management.

2.1.2 Geographical distribution in Europe

The geographical distribution in Europe is represented in figure 3.

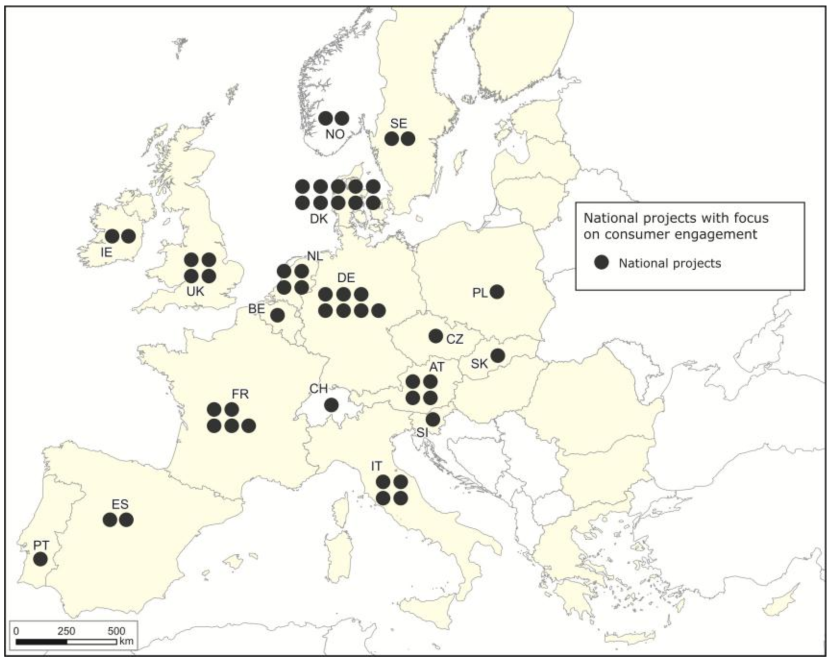

Figure 3: Geographical distribution of national projects

Figure 3 shows the distribution of consumer engagement projects in Europe. It shows the overall number of projects developed in each country. Projects are not uniformly distributed across Europe. The majority of the projects are located in EU15 Member States. In the EU 15, most of the projects are concentrated in a few countries; Denmark, Germany and France together account for more than half of the total number of projects. Figure 4 shows the number of multinational projects. Spain is leading in multinational projects participation, followed by Italy, Germany and Sweden. The number of multinational projects has been increasing since 2008 when *Address* was the first multinational project to clearly include consumer engagement within its scope of research. In 2010 *Integris* (INTelligent Electrical GRId Sensor communication), *3e-House*, *BeAware*, *Web2Energy,* and *Nobel* started, followed by *G4V*, *Green motion, Internet of Energy for Electric Vehicle* (IOE) in 2011 and in 2012 by *Meter on* and *Integrating Households in the Smart Grid* (IHSMAG.)

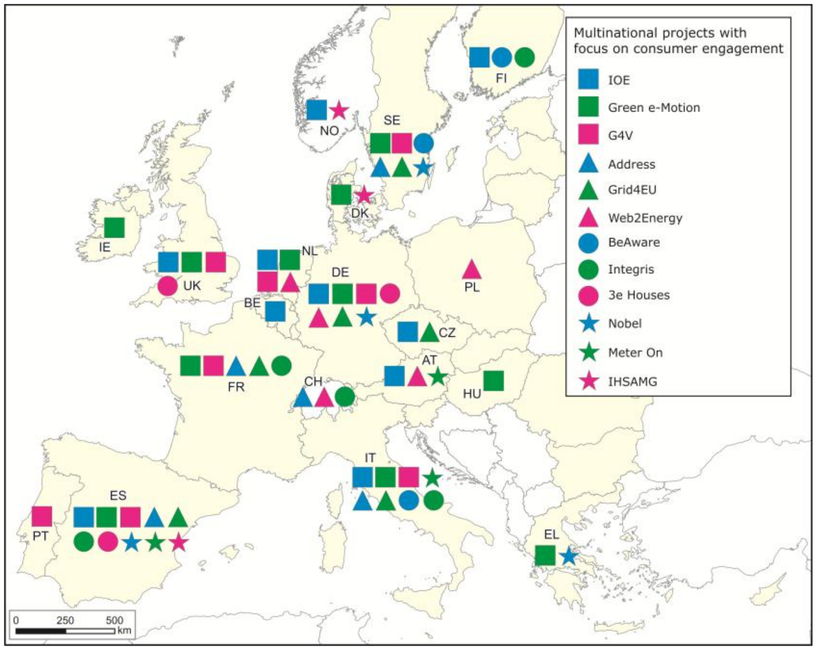

Figure 4: Geographical distribution of multinational projects

2.1.3 Motivational factors

Our analysis shows that the two points most frequently referred to as critical are the uncertainties regarding the use of different motivational factors, and the lack of trust by consumers. Understanding the values that influence consumer choice is of crucial importance to segment consumer on the basis of non-traditional factors, like attitudes and motivations associated to energy usage. These factors play a fundamental role to actually trigger behavioural change and are increasingly being used by energy providers as motivational incentives to stimulate consumer engagement and promote smart grid projects. Our survey shows that the motivational factors commonly used by smart grids projects in Europe are: i) environmental concerns, ii) reduction of/control over electricity bills, iii) better comfort (Figure 5). Most of the projects in our survey combine more than one motivational factor, usually combining environmental concerns with cost reduction. This result highlights that electricity providers are not yet targeting specific customer segments, but are approaching consumers as a whole, trying to appeal them with a combination of different motivational factors.

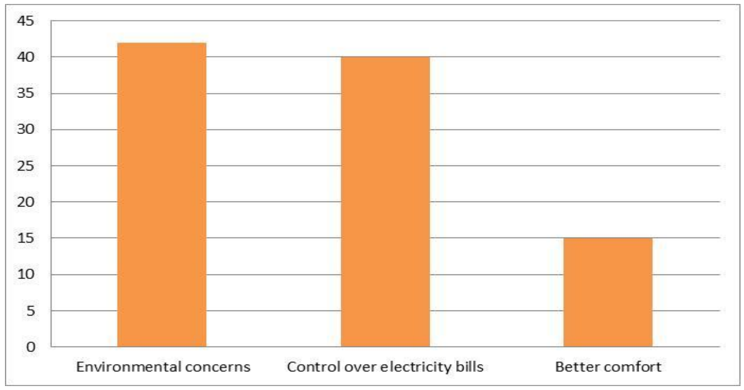

Figure 5: Motivational factors

Environmental concerns**:** from our survey, it emerges that the environmental factor is the motivational factor mostly used by projects. Several studies have highlighted that environmental considerations are becoming an important variable of consumers' choices. A consumer survey by IBM, for example, found that 70% of surveyed consumers stated environmental considerations to be an important factor in choosing energy, as well as other products (Valocchi et al., 2009). Another survey of Dutch households reveals that environmental concerns are the most important driver of a household's intention to generate its own power (Leenheer et al., 2011). Finally, a recent survey confirms that, while consumers consider reliability of supply and tariffs important, they equally place high value on broader environmental and social issues (Ngar-yin Mah et al., 2012b). Nevertheless, some studies emphasize that environmental concerns alone are not enough to engage untargeted consumers. A survey by Accenture (Accenture, 2010) reveals that the average consumer places a lower relative weighting on environmental impact when deciding to adopt an electricity management programme, compared to other motivational incentives. These studies are not specific to the European market and the extent to which their conclusions can be applied to European customers is unclear. Our survey shows that electricity providers leading consumer engagement projects in Europe consider e*nvironmental concerns* to be an appealing motivational factor very often used in combination with r*eduction of/control over electricity bills*, indicating somewhat of a lack of confidence in its effectiveness when used alone in untargeted initiatives (Gangale et al., 2013).

***Reduction of/control over electricity bills*:** 'reduction of/control over electricity bills', is the second mostly used motivational factor indicating the potential of lower electricity bills for consumers. However, a number of project coordinators have pointed out the difficulty in relation with the motivational theme 'lower electricity bills' due to the uncertainty about whether consumers will actually be able to experience those benefits. The danger here is that consumers who will not achieve the expected savings, notwithstanding their behavioural change, might consider the whole experience disappointing and frustrating (Hargreaves et al., 2010). This reaction would constitute a major blow to the consumer engagement process and could severely damage any sort of trust that may have already been established.

***Better comfort*:** the motivational factor least referred to by our projects resulted to be *better comfort*, i.e. the provision of technological solutions allowing the optimization of comfort and more control over own energy use. The consumer segment to whom this factor could mostly appeal is that of technology enthusiasts, i.e. consumers who have an interest in the technology itself, either for professional reasons or because it represents 'another gadget' (Hargreaves et al., 2010).

Another important element in engaging the consumer is ***trust***. Trust in the actors responsible for the technology (such as DSOs, regulators) has been found to influence citizen's perception of the risks and benefits of the relevant technology. There are studies that suggest that trust may result in more positive evaluation of costs, risks and benefits (Huijts, 2012). In our survey, many project coordinators reported a high level of scepticism. Customers tend to seek relationships with more mutual trust and commitment and are less sceptical when trusted organizations or figures, perceived as neutral, are involved in the project. Some projects have started building direct and personal contact with the consumer, using a combination of means ranging from information letters to one-on-one scheduled appointments; other projects have started approaching customers with an organization or person of trust, as so called 'door opener'. This has proved to be a successful strategy.

Examples from our survey include the involvement of representatives of housing associations (*Pilot Project Markisches Viertel)*, consumer associations (*EcoGrid EU*) and local authorities (*Address, eTelligencet*). This approach has been also successful in other projects outside Europe. The Smart Grid Consumer Collaborative study highlights that very positive results were achieved by those projects that partnered with trusted community groups and persons able to promote messages and programmes to large networks (SmartGrid Consumer Collaborative, 2011).

2.1.4 Successful strategies: some examples

Consumer response and consumption patterns: the observation of consumer response to newly introduced mechanisms and technical solutions is essential for the exploration of their viability as well as their impact on the energy system. Some of the projects in our survey explore consumer's response to dynamic pricing and other incentives programmes.

EcoGrid EU: consumers participate with flexible demand response to real-time price signals. The participants are equipped with residential demand response devices/appliances using gateways and "smart" controllers. Installations of smart solutions allow real-time prices to be presented to consumers and allow users to pre-programme their automatic demand-response preferences e.g through different electricity contracts. Automation and customer choice are key elements in the project.

Address: two recruitment engagement strategies were used to involve consumer in active demand programme: 1. fixed incentives for participating with 20% reduction in the bill during the duration of the field test; 2. variable incentives based on consumer's participation during the field test. The results show that the second strategies had a far greater success in involving the consumer as active player in the active demand programme.

Mini Berlin: in the project there are 50 EVs (Mini E) on the street with public access to charging points. The Mini Es function as energy storage capacity to help balance the grid during periods of high energy feed-ins by renewable energy sources. The project aims at testing the interaction of electric vehicles under everyday conditions and explores the performance of EVs not only from the technical point of view but also through the observation of users' patterns of behaviour and preferences.

Consumer engagement strategies**:** there appears to be clear evidence that for achieving consumer engagement the installation of the enabling infrastructure (smart meters, in-home displays) and provision of detailed information alone will not be sufficient. Project developers in our catalogue have started to implement diversified strategies to find the best way of presenting information to consumers - and possibly to different consumer segments - and observe their reactions to fine-tune them.

Ewz-Studie Smart Metering, Zurich aims at simultaneously assessing the response of consumers to different engagement strategies (e.g. in-home displays, expert advice, social competition and social comparison). Individual surveys before, during and after the trial allow assessment of consumer response and consumer satisfaction.

Consumer to Grid Project aims at testing and measuring behavioural change induced by different feedback means, monthly bills, a smart phone optimized website, in-home displays and an ad-hoc feedback gadget. Behavioural change is assessed by means of data verification (smart meters), questionnaires and interviews.

Many projects while only focusing on one feedback solution, typically in-home displays, also investigate the importance of using complementary means to engage the consumer.

In *ESB Smart Meter Project*, in-home displays are coupled with visual recalls such as stickers, magnets, and energy consumption visualization gadgets, which proved to be effective engagement tools. For example, results showed that fridge magnets and stickers achieved 80% recall, with 75% of users finding the magnet useful and 63% finding the sticker useful.

Some projects, also investigate the role of games in promoting awareness and engaging consumers.

B*eAware - Boosting Energy AWAREness Project* uses a system, EnergyLife, which uses wireless sensors and a smart phone to turn energy consumers into active players. This system is based on two pillars: awareness tips and consumption feedback. Awareness tips aim at increasing consumers' knowledge of the consequences of their electricity consumption while consumption feedback makes the actual energy consumption visible to users in terms of the distance to the selected saving goal. In particular, in order to engage the consumer, the EnergyLife system uses an attractive rationale where the pursuit of the savings goal follows a game-like rationale: awareness and consumption are expressed in scores; goals are divided into sub-goals and consumption are expressed in scores connected to different levels of the game, so that the fulfilment of the objective on one level gives access to a higher level; higher levels have greater difficulty and richer functionalities. Finally, knowledge is tested through quizzes and improved through tips, thus further enhancing awareness (Jacucci et al., 2009). Saving activity can be discussed with others participating in the same program. A comparative feedback may evoke feelings of competition, social comparison and social pressure that may be especially effective when relevant others are used as a reference group (Abrahamse et al., 2005).

The *Ecoffices* project is based on an "energy challenge within offices" encouraging employees to an intelligent use of energy in a fun and interactive way. Employees are challenged to participate to a collective effort aiming at "greening" their company through a competition based on real-time energy usage data of offices. There is a reward for the winning team. Employees get regularly informed of their ecological behaviour and get information on how to improve their behaviours. One of the lessons learnt concludes that it would be beneficial to add a "push information" system, such as a weekly email sent to the participants, which summarizes the main info from the web interface.

2.2 Consumer: the challenges

The analysis of smart grid projects reveals some interesting findings. In particular it highlights an increasing focus on consumer engagement in European smart grid projects and it acknowledges the increasing effort among energy providers to search for innovative methods to change the way electricity is perceived and to build a more consumer-centric relationship with their customers.

However, it is evident that most of the field studies and pilot projects are limited in the sample size and are often addressed to early adopters that are not representative of the population at large. This highlights how crucial it is to further research on human behaviour and psychological aspects in sustainable energy system acceptance. If society wants to change to a totally new energy system, people will have to change their behaviour. Indeed, energy use is all about human behaviour: it is the consumer who determines what energy to use, how much energy to consume and if to consume it in an efficient way. In the following sections we will discuss the critical issues of understanding, engaging and protecting the consumers.

2.2.1 Understanding the consumer

Research and studies in psychological aspects of energy system and on how to motivate sustainable and pro-environmental behaviour have increased in recent years (Kollmuss and Agyeman, 2002; Jackson, 2005; Abrhamse et al., 2005; Steg, 2008; Huijts et al. 2012; Venhoven et al., 2013). They recognize that human behaviour and perception are the bottleneck for many changes. However this research has typically focused on efficient energy use and addresses households as passive consumers rather than co-player in the energy system. Little is known yet on how to change and shape active participation of residential users in smart grids thus in supporting them in achieving their active role of co-player in the future electricity system (Geelen et al, 2013).

In this context, understanding consumers' beliefs, values and social interactions become of paramount importance to develop successful strategies to fully involve consumers in the future electricity system. It is not sufficient to provide knowledge for producing change; knowledge has to match values and beliefs. If the knowledge is not in line with what consumers believe, then the information provided will be disregarded (Steg, 2013). Studies show that while feedback is both necessary and valuable it is not sufficient to bring about changes in behaviours. Such a limited approach fails to consider broader social and cultural influences on household energy use. For example, ethnographic research conducted in comparable houses shows energy consumption differences of up to 300% (Gram-Hanssen, 2011; Hargreaves, 2010); this underlies the importance of the people in the home and the social aspects of their energy use (Hargreaves, 2010).

In the following paragraphs, we present a review of selected theories and approaches to consumer behaviour, sustainable consumption and behavioural change that we deem important in the process of understanding the future electricity prosumers. For an extended review on motivating sustainable consumption see Jackson, 2005.

We start with two important social-psychological theories that have been widely used to explain environmental behaviours, namely the theory of planned behaviour and the norm activation model.

The ***theory of planned behaviour*** (Ajzen, 1991) is considered an example of an adjusted expectancy-value theory (Jackson, 2005). In an expectancy-value construction people behave according to their beliefs about the outcomes of their behaviour and the values they attach to those outcomes. The behaviour is determined by the individual intention to perform it. In turn, the behavioural intention is driven by *attitudes*, *subjective norms* and *perceived behavioural control* (Figure 6). *Attitudes* towards a given behaviour depend on the beliefs about and evaluation of the outcomes of that behaviour and depend on the weighing of various costs and benefits, in terms of time, money, effort and social approval. *Subjective norm* refers to the perceived social pressure to perform or refrain from that specific behaviour. The subjective norm is constructed as an *individual belief* about what other people who are important to me think of that specific behaviour, rather than the individual personal belief about the behaviour (referred to as *personal norm*) (Jackson, 2005). *Perceived behavioural control* refers to people's perception of their ability to perform a given behaviour.

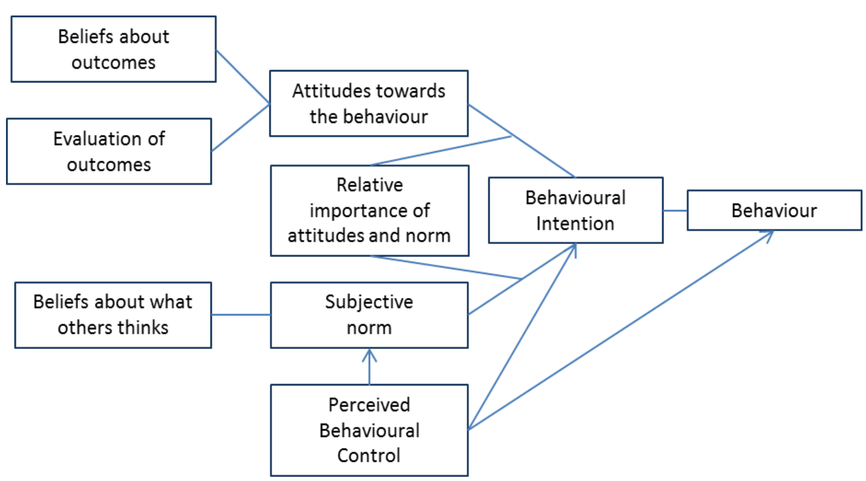

Figure 6: Theory of planned behaviour, (adapted from Jackson, 2005)

The theory of planned behaviour is one of the most influential attitude-behaviour model in social psychology, thanks also to the fact that the model is expressed in a mathematical equation that can be easily used to carry out empirical studies. The theory of planned behaviour has been widely applied to the understanding of behaviour in a vast range of different contexts and it has been most frequently used in literature to explore pro-environmental behaviour (recycling, travel mode, food choice, water conservation) and energy conservation (Litvine and Wustenhagen, 2011, green electricity consumption; Leenheer et al., 2011, intention to generate own power; Huitjts et al., 2012, sustainable energy technology acceptance; Abrahamse and Steg, 2009, household direct and indirect energy use and savings; Zhang and Nuttall, 2011, smart meter diffusion). However, the theory of planned behaviour remains an adjusted expectancy-value theory that incorporates normative influences on individual consumers through the concept of subjective norm. Moral behavioural antecedents can be included only if they are modelled as attitudinal beliefs about the outcome or evaluation of the outcome of specific actions.

Some attempts to adjust the theory of planned behaviour to incorporate moral beliefs have shown that indeed the inclusion of moral beliefs improves the predictive power of the theory in areas where pro or anti-social dimensions of behaviour are relevant (Jackson, 2005).

The ***norm activation theory*** proposed by Shalom Schwartz in 1977 is one of the most widely applied models of moral behaviour. It considers pro-environmental behaviour as a form of altruistic behaviour, since individuals have to give up personal benefits to satisfy collective interests (i.e: the environment) (Abrahamse and Steg, 2009). The theory is founded on the idea that *personal norms*, that is to say feelings of strong moral obligation that people experience for themselves, are the only direct determinants of pro-social/altruistic behaviours (Jackson, 2005; Abrahamse and Steg, 2009). Behaviour in accordance with personal norms may lead to a sense of pride while behaviour not in accordance with personal norms may lead to a sense of culpability. According to the theory, *personal norms* are activated by two antecedents: *awareness of the consequences* of one's action on the environment and *feeling of responsibility* for these behavioural consequences (Figure 7). First, a person needs to be aware of the consequences that their behaviour may have on the others and on the environment. Then, a person needs to feel personally responsible for these behavioural consequences (ascription of responsibility).

The relationship between personal norm and behaviour is stronger in the case where people are aware of the negative consequences and feel personally responsible for these negative consequences. In the case where one is unaware of negative consequences and denies responsibilities the link is weaker. The norm activation theory has been successfully applied to a range of pro-environmental behaviours and energy conservation (Abrahamse and Steg, 2009; Steg et al. 2005).

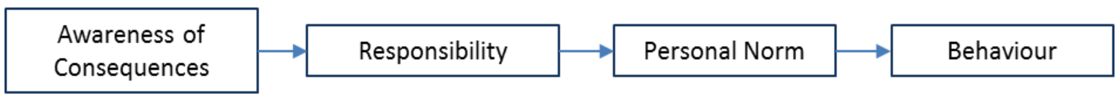

Figure 7: Norm Activation Model (adapted from Jackson 2005)

However, research shows that norm activation model seems to be successful in explaining low-cost environmental behaviour, but appears less effective when the behavioural settings are characterized by strong constraints on behaviour, e.g. when the behaviour is too costly in terms of effort, money or time (Steg et al., 2005).

Stern and colleagues (Stern, Dietz, Abel, Guagnano, & Kalof, 1999; Stern, 2000) proposed the ***value-belief-norm theory.*** The theory postulates that environmental behaviour results from *pro-environment personal norms*, i.e. a feeling of moral obligation to take pro-environmental actions (Figure 8). These personal norms are activated by beliefs that adverse consequences threaten things that the individual values (awareness of consequence for valued objects, AC) and beliefs that the individual can act to reduce this threat (ascription of responsibility to self, AR). The value-belief-norm theory proposes that awareness of consequences and ascription of responsibility beliefs are dependent on general beliefs on human–environment relations (as the new environmental paradigm (NEP) whiting which human activity and a fragile biosphere are seen as inextricably connected) and on relatively stable value orientations. Typically, three general value orientations are distinguished: an *egoistic value* orientation, where people try to maximize individual outcomes, an *altruistic value* orientation, reflecting concern for the welfare of other human beings, and a *biospheric value* orientation, reflecting concern with non-human species or the biosphere. Self-enhancement (egoistic) and self-transcendent (altruistic and biospheric) values seem to be particularly relevant to understand beliefs, preferences, attitudes, norms and behaviour in the environmental domain (Venhoeven et al., 2013). The stronger the biospheric and altruistic values, the more likely the person will accept the new environmental paradigm; the stronger the egoistic value, the less likely the person will accept this paradigm. The causal chain proposed in value-belief-norm theory moves from relatively stable and general values to beliefs about human–environment relations (NEP). These beliefs about human-environment relations lead to awareness of the environmental consequences of one's actions and this in turn leads to awareness of one's responsibilities to reduce those consequences. Based on this, the person develops a personal norm to engage in pro-environmental action (Steg et al., 2005; Jackson, 2005).

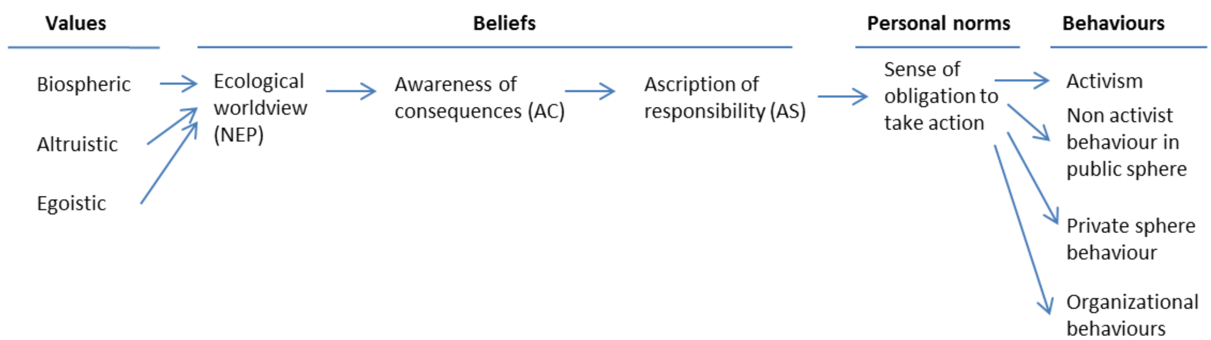

Figure 8: Value-Belief-Norm Model (adapted from Stern, 2000)

Stern explicitly acknowledges that behaviours may result from multiple motives. Different value orientations may coexist in the same individual and may be differently prioritized according to the specific social context. Stern argues that individual behaviour derive from the set values that receive attention in a specific context.

The argument that individual behaviour stems from saliency of specific contextual values finds support in the ***focus theory of normative conduct*** developed by Cialdini (Cialdini, 2006) that addresses the influence of social context on personal conduct. According to this theory two kinds of norms exist: a *descriptive norm* that refers to what perception we have of what is normal in a given situation; an *injunctive social norm* that explicitly reflects the moral rules and guidelines of the social group. Injunctive norm tends to motivate and constraint our action through the promise of social rewards or sanction (Jackson, 2005). The effect of social norm in guiding individual behaviour has been demonstrated in recent research on energy conservation. Allcott (Allcott, 2011) demonstrated that the use of comparative electricity bills that employs *injunctive social norm* (conveying the message that energy conservation is pro social) affect consumer behaviour. The study demonstrated that non price-intervention can substantially and cost-effectively change consumer behaviour.

With new insight from motivational and social psychology theory, Lindenberg & Steg (2007) introduce **goal framing theory** which postulates that "goals govern or "frame" what people attend to, what knowledge and attitudes become cognitively more accessible, how people evaluate various aspects of the situation, and what alternatives are being considered" (Lindeberg & Steg, 2007, p. 119). This theory proposes that environmental behaviour is guided by three overarching goals: *hedonic goals, gain goals and normative goals.* Hedonic goals lead individual to focus on ways 'to feel better right now' such as avoiding effort, seeking direct pleasure or seeking excitement. Gain goals lead individual to focus on 'improving resources' such as money and status. Normative goals lead people to focus on 'acting appropriately' and make them particularly sensitive to what they think ought to be done, such as contributing to a clean environment or showing appropriate behaviours. Goal framing theory suggests that one goal is strongest in a particular situation and mainly influences preferences and decisions, while the other goals are in the background and influence the strength of the focal goal. Values determine the likelihood that a particular goal is strongest in any situation, as they influence the extent to which goals are chronically accessible. This implies that normative goals to act appropriately are more likely to be strong in a particular situation when people strongly endorse altruistic or biospheric values, while gain goals are more likely to be central when people strongly endorse egoistic values. Lindenberg & Steg (2007) suggests that it may be useful to distinguish two types of self-enhancement values to understand environmental beliefs, attitudes, norms and actions as well, namely, egoistic and hedonic values. They suggest that hedonic values are an important predictor of environmental beliefs, attitudes, norms, and behaviour, as hedonic goals are more likely to be activated among those who strongly endorse hedonic values. Therefore there is research that supports the importance to distinguish two types of self-enhancement values to understand environmental beliefs, attitudes, norms, and actions*: hedonic values* and *egoistic values*. More specifically, studies in the Netherlands, Japan, Indonesia and Mexico validated the distinction between hedonic, egoistic, altruistic, and biospheric values indicating that hedonic and egoistic values form distinct value clusters. Hedonic and egoistic values were found to be correlated and this is in line with the value typology proposed by Stern (Stern, 2000), as both reflect self-enhancement values. Recent research indicates that it is indeed important to include hedonic values in studies on environmental beliefs, preferences, norms and actions (Steg, 2013). Based on the goal frame theory, Steg et al. (2014) propose a theoretical framework, the **Integrated Framework for Encouraging Pro-**

Environmental Behaviour that suggests two basic strategies to encourage pro environmental actions: the first strategy focus on reducing the conflict between hedonic and egoistic goals on one hand and normative goals on the other end; the second strategy focus on strengthening normative goals, therefore weakening the relative strength of hedonic and gain goals. Though the first strategy is important when pro-environmental behaviours are costly, it may lead to not sustained pro-environmental actions (people will stop to act pro environmentally only as long as it is pleasurable and profitable to do so). On the other hand, strengthening normative goals can encourage pro environmental actions even when these actions can be somewhat costly. Steg et al. propose that the strength of normative goals depends on which values people endorse as well as on situational factors/cues that activate and support the accessibility of these values. We will borrow from this approach in developing our approach to a model of the electricity consumer that we will present in section 2.2.3.

2.2.2 Engaging the consumer

The electric power system, for much of its history, contributed to large extent to disengage customers from the upstream side of the meter simply because the technology did not allow for anything else. Industry has made it easy and simple for consumers. In parallel to the technical transformation of the smart grid, end users need to undergo a cultural change to become active participants. The role of consumers is among the biggest and most challenging pieces of the smart grid puzzle, as they have their own and varied needs and priorities and they may and may not behave as experts and engineers want them to. The idea of getting the consumers to become active participants in the market is still novel to many in the power industry and even more so to the average consumer who has been successfully trained to be a passive user (Sioshansi, 2011). There is the need to understand the consumer in order to develop strategies to motivate and involve it in the future electricity system. In summary, things should be moving towards reengaging the disengaged customer.

The process of electricity consumer engagement is tightly related with the evolution of the electricity networks. Empowering the consumers to manage their electricity consumption, while enabling them to actively contribute to the operation of the distribution network, requires taking full advantage of the capabilities of smart grid technologies. Figure 9 depicts the level of consumer engagement in line with the evolution of the smart grid potential. The initial level of consumer involvement takes place through the provision of accurate house electricity bill as a result of advanced metering infrastructure (smart metering) installed in the customers' premises. This indirect feedback does not necessarily motivate consumers to reduce energy consumption or trigger energy efficiency. In addition, this initiative is in most cases considered as utility driven and oriented to deal with utility operational issues such as outage management and reduction of commercial and technical network losses rather than addressing concerns regarding in-home management and consumer responsiveness (FERC, 2008). The next level of consumer involvement includes several different types of indirect feedback, such as aggregated (i.e. whole-house) feedback as well as appliance and end-use disaggregated feedback (e.g. estimated appliance-specific, historical comparisons, social comparisons, etc.). These types of feedback are provided by means of web-based presentations and utilize a variety of data sources including electric utility data and other existing types of data (e.g. home energy audits). Able to deliver processed feedback to the consumer's IT equipment (e.g. computer, smart phone, etc.), the suppliers or third-party service providers can empower the end user with mainly two types of feedback: 1) basic energy consumption and cost information, where a customer learns by doing, and 2) leverage existing data to provide personal and social contextual feedback. The second type of feedback provides information about the energy use patterns of other households so as to provide a contextual frame from which any given household can assess their energy consumption performance relative to other people in similar circumstances. Comparisons with neighbors, friends, and communities provide a social context and information about what actions others are taking (Allcott, 2011). Moving to (nearly) real-time, direct feedback provides a wide range of contextual knowledge to users and enables users to learn by doing as well as through the provision of more tailored and socially-relevant feedback.

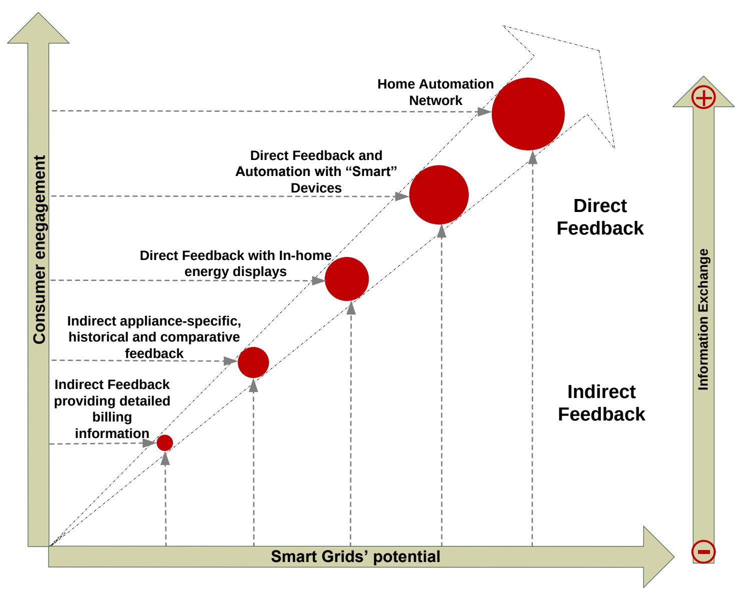

Figure 9: Consumer engagement vs. smart grids' potential (Vasiljevska, 2013)

For instance, in-home energy management displays provide the potential for "learning by doing" when the user carries the device through the home while switching on and off devices. The user receives immediate, appliance-specific feedback that allows him/her to learn about energy in an incremental way. The next level of end user empowerment consists of energy efficient and "smart" (automated) appliances that can provide direct, real-time feedback, and include appliance-specific information as well as automation. Another critical feature of these smart devices is their capacity to receive pricing signals and utility load control in some cases leading to potential alleviation of distribution network capacity or distribution infrastructure upgrade and thereby reduction of DSO capital expenditures.

Finally, at the core of the ultimate dialogue between the supplier and the electricity end-user is the highest level of real-time feedback: home energy management system, including energy generation and storage systems. This combines all the types of feedback previously described, including energy efficiency and automation enabling technologies. The complete home energy management system includes a complete network of residential wireless and wired sensor networks, display and feedback devices, and automation that may communicate with the utility. The home automation or home area network supports complete energy management, including information and control for the residential home through a wide selection of interoperable products and services and can effectively integrate smart appliances, distributed renewable generation, and electric vehicles over time.

2.2.3 Protecting the consumer

Smart grid appears as a complex system which integrates physical, cyber and social systems. The complexity can be mainly addressed to two main factors: existence of interdependent infrastructures (physical, information, communication, social, etc.) and the distributed nature of control and monitoring functions. In addition, a system heavily dependent on ICT introduces significant challenges to cope with. In this context, the EU Commission's Smart Grid Task Force EG 2[2] states that the level of "smartness" should always be considered in relation to the cyber-related risk, cost, public image and consumer trust. Consumers are concerned about a broad range of issues that include cost, loss of control (including utilities' ability to arbitrarily or accidentally shut off the service), health effects of radio frequency, safety, privacy and data protection, fairness, uneven distribution of effects and the impact that smart grid may have on vulnerable groups such as fuel poor, elderly or people who are less familiar with IT.

[2] http://ec.europa.eu/energy/gas_electricity/smartgrids/taskforce_en.htm

These concerns have been reported worldwide (Nagar-yin Mah et al., 2012b; Krishnamurti et al., 2012). The 2009 internal energy market legislation (EC, 2009) clearly establishes, together with common rules for the generation, transmission, distribution and supply of electricity, consumer protection provisions, with a view to improving and integrating competitive electricity markets in the Community.

Below we present some of the main concerns that have been highlighted in our analysis and in the literature.

Data Privacy and Security

An indirect risk of smart grid is the violation of consumer's privacy. AlAbdulkarim (AlAbdulkarim, 2013) defines *privacy* as the right of electricity consumers to be guaranteed adequate measures of protection of their personal data maintained by the system, to prevent disclosure of this data to unauthorized parties and prevent unlawful deduction of further information from the data, which can reveal private aspects of consumers' behaviour and habits. The consumers are not only concerned with confidentiality, but also with data sharing and retention. These concerns are linked to the possibility of identifying consumer general behaviour patterns from their appliance usage (*individual patterns)*, to monitor consumer behaviour as it happens (*real time surveillance*), to sell consumer information to third parties to profile individuals (*information detritus*) and to determine whether a person is at home (*physical invasion*) (Krishnamurti et al., 2012).

The data privacy issue has served as an argument for the Dutch government to renounce plans for mandatory implementation of smart meters in the Netherlands (KEMA, 2010). The report states that from a legal standpoint smart meters pose a legal dilemma since the frequent readings threaten the respect for private and family life according to the Convention for Protection of Human right and Fundamental Freedoms (KEMA, 2010). This resulted in granting the consumers with an opportunity to opt for a smart meter under "administrative-off", assuring no data can be exchanged with the DSO or any third party and thus disabling the possibility of remote control and disconnection.

Therefore, the ability of regulators and companies to control and secure data privacy will have a large influence on how willing consumers are to move towards smart grid deployment.

Related to the issue of data privacy is the grid cyber security. While the two-way consumer-utility communication and internet-transferred data will account for sustainable and efficient delivery of electric energy, while placing the consumers in the focal point, it also makes the grid vulnerable to external attacks. These attacks could range from remotely disconnecting customers to hacking a network to adjust load conditions, which could ultimately result in electricity network instability.

Securing the electricity network requires protecting a variety of devices connected to the grid that heavily rely on wireless technologies. The EU Commission's Expert Group 2, Smart Grid Task Force argues that the data privacy and security should be addressed at the design phase of the smart grid, i.e. prior to the development of the smart grid systems and processes. One of the key features of the "privacy by design" strategy is the approach towards data handling, namely: data control and access rights, data use, data storage and data sharing.

Furthermore, it must be clear whether and what data processed for smart metering are the personal data and thus whether the EU data protection framework applies. Two types of data are processed within smart metering (EC Smart Grid Task Force EG2, 2011):

- personal data – definition in accordance with the Data Protection Directive
- technical data – any data needed for maintenance of the grid.

In addition to the "privacy by design principle", mechanisms shall be implemented for ensuring that, *by default*, only those personal data are processed which are necessary for each specific purpose of the processing and are especially not collected or retained beyond the minimum necessary for those purposes, both in terms of the amount of the data and the time of their storage.

Vulnerable consumers

Vulnerable consumers are consumers that have difficulties in accessing products and services that suit their needs due to their particular conditions such as long term ill health, age or financial situation (Neuburg, 2013). The 2009 internal energy market legislation (EC, 2009) introduced an obligation for Member States to take appropriate measures to protect vulnerable consumers. In particular, each Member State shall define the concept of vulnerable customers which may refer to energy poverty and, inter alia, to the prohibition of disconnection of electricity to such customers in critical times. The directive recognizes the diverse situations of energy consumers in different parts of the EU; the Commission does not consider it appropriate at this stage to propose a European definition of energy poverty or of vulnerable customers (EC, 2010). Therefore, each member state has different approach strategy to the vulnerable consumer and respective issues to be tackled with.

For instance, the UK 'Safety Net' initiative[3] guarantees to never knowingly disconnect a vulnerable customer at any time of year, where for reasons of age, health, disability or severe financial insecurity that customer is unable to safeguard their personal welfare or the personal welfare of other members of the household (Eurelectric, 2013). In addition, the Safety Net provides enhanced measures that are

3 www.energy-uk.org.uk/publication/finish/3/287.html

integrated into all suppliers' debt management processes, an agreed universal definition of a potentially vulnerable customer, improved communication with support agencies, a range of debt management and repayment options and follow-up procedures to support vulnerable customers.

The EU Parliament report[4] on "vulnerable consumers" calls for a genuine EU strategy to systematically and comprehensively strengthen the rights of vulnerable customers. The same report underlines that the consumer vulnerability should be tackled by strengthening legislative powers and promoting a sectorial approach, since the variety of different forms of vulnerability makes the adoption of a single uniform instrument impossible.

Fuel poor

A fuel poor household is defined as a household that cannot afford to keep adequately warm at reasonable cost. The World Health Organisation (WHO, 2007) notes that the term "fuel poverty" does not necessarily mean that a household is 'poor' in the traditional sense, and suggests to consider a definition that is less based on a concept of poverty and is more targeting the home. It argues that the main risk factor is inadequate housing and that fuel poverty is to be seen as a result and not as a cause of that. At national level, definitions of fuel poor household exist in the UK and Ireland where it is considered to be a household which needs to spend more than 10% of its income on all fuel use and to heat its home to an adequate standard of warmth. This is generally defined as 21ºC in the living room and 18ºC in the other occupied rooms - the temperatures recommended by the World Health Organisation (Derby, 2012). Smart grid technology may present some positive aspects in relation to fuel poor: - smart meters to facilitate prepayment and avoid higher unit prices; - energy displays can help consumer to visualize their energy use and alert them in case of unusual patterns, - benefit of preferential access to cheap electricity (in case of abundant supply) (Derby, 2012). However, smart grids are still surrounded by uncertainty, in particular for what concerns social and economic factors. This uncertainty strongly suggests a need to involve a wide spectrum of system users, including the fuel poor, in the trials of new technology and even in the design of those trials (Darby, 2012). For example, it is not yet clear what kind of direct or indirect impacts the EU policy on smart metering may have on household in fuel poverty. The European Commission communication on smart grids doesn't make any reference to fuel poverty or equity issues in smart grid deployment.

[4] http://www.europarl.europa.eu/sides/getDoc.do?type=TA&language=EN&reference=P7-TA-2012-209

Health concerns

Recent studies (Krishnamurti, 2012; AlAbdulkarim, 2013; Consumer Futures, 2013) report on consumers concerns regarding the adverse impact on health caused by the electromagnetic waves emitted by the meter. While many consumers are willing to adopt technologies that emit electromagnetic wave such as mobile phones or Wi-Fi communication, some still object to wireless smart meters due to fear of prolonged exposure to the radiofrequency emitted by the smart meter. Although evidence to date suggests that exposure to radio wave produced by smart meters do not pose a risk to health, it is important that consumer's anxieties about the health impacts of smart systems are taken seriously. In addition, anxiety about possible health impacts of smart systems could cause delays or indeed threaten their installation (Neuburg, 2013). Moreover, increased awareness of adverse health effects has resulted in numerous activist-campaigns demanding that the consumer be given the right to choose (AlAbdulkarim, 2013).

2.3 Towards a model of electricity consumer

Research on behavioural change in energy related behaviour has typically focused on motivating the consumers in their passive role. With smart grids the consumers will assume an active role as energy users and producers. Therefore, the challenge ahead is to understand the consumer active role and participation in smart grids, including the relation with the DSO and other service actors, and among and across the communities of consumers (Geleen et al, 2013). Stern, 2000 argues that for behaviour change to occur consumers must have the right information, possess or adopt consonant norms and values (or receive financial incentives), translate those motivations into action, and maintain behaviour change over time. In this view, and based on the available theories on behavioural change, the focus of current research at JRC is to conceptualize a model of the electricity prosumers and to model prosumer behaviours through computational simulation methods. In Figure 10 we summarize the elements that need to be taken into consideration in modelling the electricity prosumer, based on the theories of consumer behaviour reviewed earlier in this report. Modelling the electricity prosumer presents several new challenges. As some authors argue (Hargreaves, 2010), electricity is "doubly invisible" to households. Electricity is an invisible and abstract force entering the household via often hidden wires. Moreover, most energy consumer behaviours are part of regular routines and habits making difficult for people to connect specific behaviours to the energy they consume. Finally, the energy prosumers will have to face the challenge of becoming active player, role that will bring about concerns over privacy and security.

In order to promote and encourage the active role that the electricity prosumer will have to play in the future smart grids we need:

- to understand and engage the prosumer,
- to turn intention into action (behaviour),
- to maintain behaviour over time,

while at the same time protecting the prosumers from any risks that may arise.

In Figure 10 we visualize an approach based on the goal framing theory where individual behaviour is guided by three overarching goals: *hedonic goals, gain goals and normative goals.* Self-enhancement values (egoistic and hedonistic) and self-transcendent values (altruistic and biospheric) determine the likelihood that a particular goal is strongest in any situation, influencing the extent to which goals are chronically accessible. These values influence behaviour indirectly via behaviour-specific beliefs, preferences, attitudes and norms. The strength of one specific goal depends on which values people endorse as well as on contextual factors that may activate and support the accessibility of specific values. Indeed the presence of new contextual factors, such as technological advances (e.g. smart metering) and associate concerns (e.g. data privacy and security), climate change, energy retail market restructure, etc. requires closer inspection of factors leading to technological acceptance and adoption of consumers' behaviour to the new environment. In this context, *understanding* and *motivating* the prosumer necessitates its characterization according to its personal traits or environmental values. Individual do not act in isolation and will adjust their behaviour according to social norms. In particular, as earlier discussed, Cialdini et al. (2006) distinguish between two types of social norms, descriptive and injunctive. The former simply involves perception of which behaviour are typically performed, the latter express the perception of which behaviours are typically approved or disapproved. Recent research (Allcott, 2011) argues on the added value of using the descriptive and injunctive norm in tandem.

In considering a model of electricity prosumer, we have to bear in mind that energy consumption is a social and collective process rather than an individualized one. There are gender and age specific styles of engagement with devices (smart energy monitors) and what they communicate that can lead to greater cooperation or conflict in the household. It is argued that the introduction of energy efficient technology into the household may theoretically lead to change in energy consumption. However, when behaviours in the household are not aligned, potential energy savings gains may not be realized.

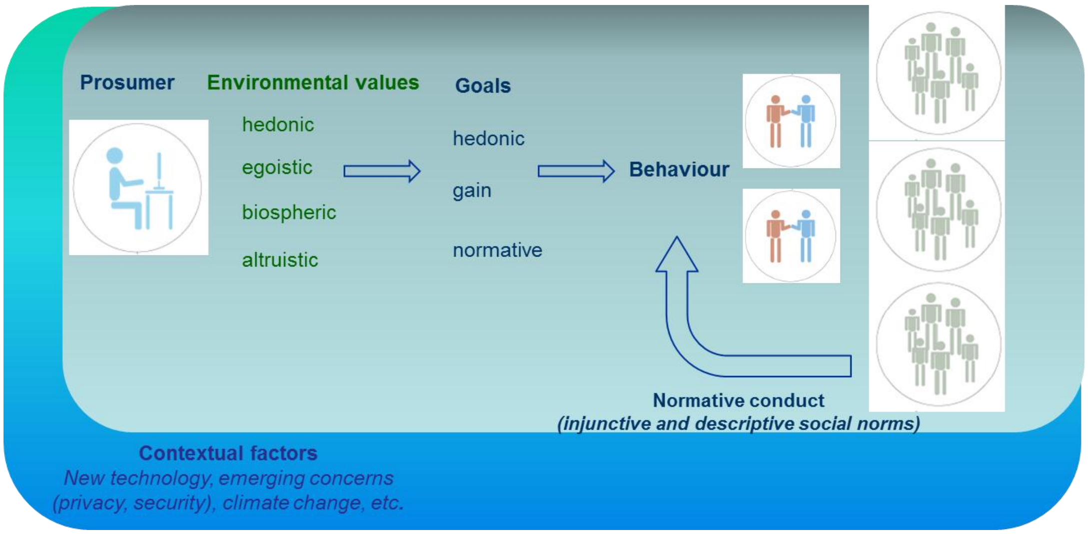

Figure 10: Model of an electricity prosumer

Differences in behaviour of end users have been found to contribute to the variability in household energy consumption levels. For example, some research result found that more than 40% of the electricity consumption in households could be linked to lifestyle factors; approximately 12% of the variation in energy user for space heating could be explained by occupant behaviour; approximately 20% reduction in household carbon emissions could be achieved by behavioural changes (Geleen et al., 2013) It is suggested that future research should focus more on the household and more on the individual energy consumer as key unit of analysis. Some authors argue that fostering cooperative and energy savings household dynamics can have better results than educating people (Hargreaves et al., 2010).

In recent years there has been an increasing trend of using agent based simulation in residential energy research (Chappin and Afman, 2013; Zhang and Nuttall, 2011) in order to approach the complexity of the problem. The idea is to model in a virtual environment the electricity prosumers who, while acting in a smart grid context, behaves and interacts with other actors at household, community and societal level. This is the line of research that JRC will explore bearing in mind that domestic energy consumption is a social and collective process rather than an individualized one.

3. THE COMMUNITY

One of the biggest achievements of future smart grids will be their distributed mode of operation where the coordination of energy consumption will become first priority. A vision of "community grid" that relies mostly on local energy sources and storage is gaining acceptance. Whilst conventional energy production capacity used to be predominantly owned by a small number of large utilities, an increasing number of installed renewables are now owned by citizens, farmers and energy cooperatives. Such cooperatives present an interesting form of social innovation in which citizens together develop completely new ways to organize the energy system driven by a sense of community and local ownership. Local governments are starting to line up behind such a decentralized energy future, thereby increasing its clout (Bosman, 2013). Some studies argue that decentralized and community driven renewable energy is the "fuel for a more democratic energy system" (Skopik, 2013) and, for the smart grid to be successful, policies should be designed to enhance the autonomy of communities (local group of end-users) to support them in applying renewable sources and limit the power supplied by central power plants (Wolsink, 2012). The challenge will be to enable consumers into forming communities according to their energy consumption behaviour. These communities will interact with other grid stakeholders to coordinate energy consumption plans and set up private energy sharing alliances (Skopik, 2013).

Studies reporting about community engagement in renewable energy and smart grids project highlight the essential role of building trust between local people and groups in taking project forward (Walker et al., 2010; Alvial-Palavicino et al., 2011; Wolsink, 2012). Local cooperatives with groups of houses sharing micro-generator production are also emerging. Two examples from The Netherlands are Texel Energy and Grunneger Power (Geelen et al, 2013). These cooperatives aim to organize the production of local renewable energy and aim to balance supply and demand to optimally utilize locally produced energy. As households locally produce renewable energy, energy stakeholders from the government and private sector try to involve residential users in the supply and demand management of electricity in smart grids (Geelen et al., 2013). Being part of communities should strengthen consumer's energy awareness by allowing comparisons of energy consumption data with other community members.

However, some recent studies on community energy argue that there is a limit to how much groups can achieve on their own. Instead, external sources of support are required to succeed and this indicates the strong need for consistent policy support, as well as intermediary networks, to ensure community energy projects have the resources they need to progress and achieve their objectives (Seyfang, 2013).

Community based approaches to social changes are becoming an increasingly important part of the landscape of sustainable development. In particular, approaches that uses community based social marketing are gaining field. Social marketing is an approach that seeks to identify the barriers that people perceive when attempting to engage in a certain activity. Community based social market merge this approach with insight into the importance of social norms and community engagement in changing that behavior (Jackson, 2005). Successful examples of the application of this approach show that well designed community based social marketing strategies can have significant impact on routine behaviors and can offer effective paths towards pro-environmental and pro-social behavior. It follows that communities may have an important role to play in mediating individual behavior. Further research and analysis is need to understand the attributes that define (electricity grid) community, identifying the strong elements that can make a community relevant in the development of future smart grids. In Figure 11 we present a simplified representation of a community electricity grid.

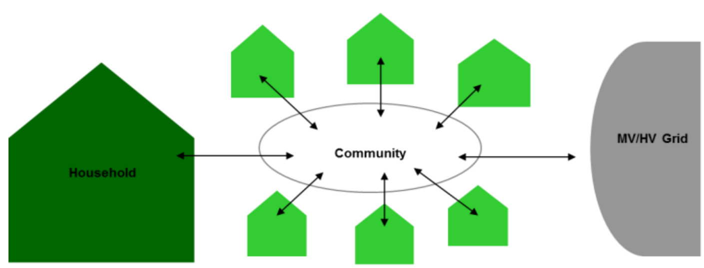

Figure 11: Smart grid framework at household and community level (adapted from Geelen, 2013)

4. THE SOCIETY

Social sustainability, though still a fuzzy concept, can largely be associated with the quality of life in our society (and its inequalities, health and employment issues) now and in the future (Ribeiro et al., 2011). For the smart grids to be successful and sustainable there is the need to include at an early stage an evaluation, at societal level, of the uncertainties and externalities that future smart grids might present. Many articles and reports highlight the importance of including externalities of smart grids such as the impact on job, the shortages of technical workforce (ageing work force), new skill requirements, safety and organizational and management issues (Riberio et al. 2009; Giordano et al., 2011; KEMA, 2009). In the following sections we will present an overview of the main challenges of future smart grids from a societal point of view. Each of the challenges presented below needs further analysis and research. This is out of the scope of this report.

4.1. Externalities in smart grids

The review of available public reports and scientific publications highlights several social implications of smart grids that should be taken in consideration (Giordano et al., 2011).

Jobs: in USA 280 000 new direct jobs (2009-2012) and more than 140 000 new direct jobs will persist beyond smart grids deployment (KEMA, 2009); job creation will provide an annual benefit of 215M$ (NETL, 2009); in the US the electricity sector a major job market for early-career engineers is shaping up in US electricity sector: the power industry need to hire thousands of new engineers by 2030" (Thornton, 2010). On the other hand: in former EU15 almost 250 000 jobs were lost in the electricity sector since 1995. Merger and acquisition will also play a part in employment decline with large scale operations rendering many employees redundant (EUROFOUND, 2008).

Ageing work force – gap in skills and personnel: "greying workforce": in the next five to 10 years many utilities will lose their current workforce to retirement (WEF, 2010); nearly 25 to 35 % of utility technical workforce will retire within 5 years; in the USA the average utility worker is 48 year old, five years older than the median age for US workers; the power industry needs to hire thousands of new engineers by 2030 (Thornton, 2010).

New skill requirements - training: the new job profiles require high level of flexibility, adaptability, customer focused approach, sales skills, regulatory expertise. There is the need for investment in the development of relevant undergraduate, postgraduate and vocational training to ensure the building of a sufficient pipeline of next generation, smart grid- savvy electrical engineers (WEF, 2009). Adequate training, re-skilling, up-skilling of the workforce is essential.

New pools of skills and knowledge: China is the largest producer of engineering graduates in the world: 600,000 engineering graduates in 2009. India: 500,000 engineering graduates a year. United States: 70,000 engineering graduates every year. All of Europe: 100,000 engineering graduates. (WEF,2010). There is the need for smart grid investors to look beyond national borders.

Organizational and management issues: a shift from small and medium enterprises (SMEs) to big corporation is expected due to merger and acquisition there is a change of view on personnel and human resources that start to be considered as highly strategic (EUROFOUND, 2008);

Safety: some reports argue that the reduction of hazard exposure can generate an annual benefit of1M$ (NETL, 2009; WEF, 2010); fewer field workers because of smart metering would impact on safety.

All these aspects should be considered when considering the future smart grid from a societal point of view.

4.2. Insight from European smart grid projects

The social aspects listed above were included in the 2012 JRC survey (Girodano et al., 2013). However, we have to acknowledge a low rate of response in this specific section on social implications of smart grids. Very few projects seem to anticipate possible impacts of smart grid development or address problem linked to social sustainability and social acceptance. This confirms that social and cultural implications are not yet duly taken into consideration in smart grids projects in Europe. Some answers from the survey provided some insight in issues of health concerns and transparency. For example, the E*COFFICE* project reports concerns from participants over the effect of wireless emission generated by the sensors / meters installed for the project. In the PREMIO project special attention was given to the social acceptance of the project, particularly among the housing units of the experiment. Project presentations were conducted throughout the project. Moreover hosts had personalized access on the project website to access to their personal data, including power consumption. In the *Electric mobility pilot region of Berlin-Potsdam, Project "BeMobility 2.0"* project neighbourhoods were concerned about noise and safety of vertical axis wind mills. The project addressed these concerns by informing the neighbours and by sharing research about noise from wind mills. JRC will continue to monitor these aspects in its ongoing survey of smart grid projects in Europe.

4.3. Cultural considerations

Social and cultural factors and norms play a very important role in smart grids since they shape people's behavior. Cultural values vary among nations and can lead to different approaches and behaviors. Studies have shown that cultural values of environmental resources can lead to drastically different approaches and reactions (Kollmuss, 2002). Cross cultural studies that look at different attitudes and behavior on smart grid technologies would indeed be very valuable. Smart grid focusing mainly on techno-economic aspects may cost orders of magnitudes higher than originally estimated due to the inability to take into account the impact to the most affected stakeholders, the electricity consumers.

In the smart grid context, social media can play an important role in increasing interaction between utility and consumers; some utilities have launched twitter sites for communication between company and consumers, very useful in case of emergency (WEF, 2010). Cultural orientation and its effects on individuals have been extensively researched, though with mixed findings. Cho et al. (Cho, 2013) acknowledges the need to further explore cultural orientations in environmental behaviour in order to identify the cultural antecedents of consumers' environmental behaviour.

4.4. Smart grid and socio-economic development

Some authors argue that the emerging concepts, systems and technologies grouped under the term "smart grids" may offer an important contribution to achieving universal access to electricity (Welsch et al., 2013). Thanks to smart grid technologies, it is argued that sub-Saharan Africa countries may accelerate and improve electrification efforts. Welsch and colleagues introduces the concept of *Just Grid* to convey the need for power systems to contribute to equitable and inclusive economic and social development without marginalizing the poor. Further discussion on power transmission system in Africa suggests that Sub-Saharan Africa should adopt a new electricity supply model of integrated resources planning characterized by high penetration of distributed resources that include energy conservation and increased consumer participation. Locally available renewable resources would cost a fraction of long delivery networks and could in fact service many moderate loads (Sebitosi and Okou, 2010). However cultural consideration and technology adoption should be verified: there is no evidence at the moment that this could be the winning solution.

As part of the commitment to achieving the objectives of the “Sustainable Energy for All” initiative, the European Commission announced their “Energizing Development Initiative”[5], which will provide

5 http://www.se4all.org/commitment/energizing-development-initiative/

developing countries with the support they need to assist them in providing access to sustainable and more efficient energy. The goal of the initiative is to provide energy services to 500 million people by 2030. An indicative example is the "Lighting for all" initiative in Brazil, with a main target to enable electrification of rural areas. In areas, such as Amazonia, grid-based electrification did not appear to be realistic, mainly due to very sensitive eco-system in the area and lack of cost-effectiveness, i.e. need for high investments for a benefit of few and dispersed consumers with low income and consumption rates. To this end, electrification schemes based on decentralised systems and exploitation of the renewable energy potential appear as viable solution for providing electricity to isolated communities.

4.5. Smart grid acceptance

Public acceptance of any new technology is a crucial matter to be considered at an early stage of product development. To this end, the smart grid is not an exception and its successful implementation relies on placing the electricity consumers in the focal point of the process. Inducing behavioral change requires close interaction with the end-user in order to understand which factors can lead to behavioral change and then develop the necessary technology, instead of the other way around.

Stern (Stern, 2013) suggests several ways to increase consumer acceptance of smart grids:

- ease and simplicity of smart grid technology use;
- visibility: information provision of clear benefits due to smart grid deployment, including long-term financial benefits;
- Observability: use of pilot projects increase observability and reduce consumer concerns.

Davis (Davis, 1989) refers to two two socio-psychological factors in the technology acceptance model that may influence pro-environmental behaviour: perceived ease of use as a degree to which the consumer evaluates technology being easy or difficult to use, whereas perceived usefulness is a degree to which the user evaluates whether the technology is useful and advantageous compared to the previous (or other) technology. Studies (Venkatesh & Davis, Stragier,2010) argue that perceived ease of use has a strong influence on perceived usefulness, which in the context of smart metering technology may indicate that consumers consider the smart meters useful if they are easy to use (Stragier, 2010).

Despite public involvement in the form of consultation processes, the social acceptance of large infrastructure projects is mostly interested in the ‘passive’ consent for the construction of such projects. However, micro-generation technologies and more generally, smart grids, do not only impact in individuals’ environments (‘spoiling of the landscape’, noise etc.), but also necessitate individuals' 'active' acceptance in terms of the willingness to install these technologies in their homes. This more active involvement may take different forms: provision of the site for these installations, outlay of the up-front capital investments or behavioral changes.

We endorse the distinction of three kinds of acceptance (Huijts, 2012) that well applies to the approach adopted in this report (Figure 12).

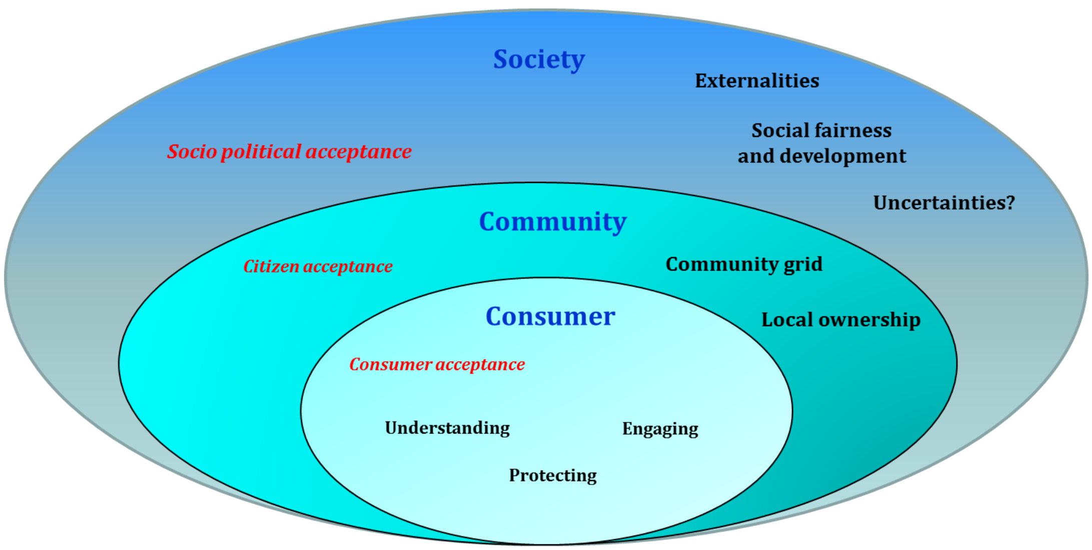

Figure 12: The social dimension of smart grids: a framework

Consumer acceptance: reflects the public's behavioural responses to the availability of technological innovations, that is, the purchase and use of products and services offered;

Citizen acceptance: behavioral response to situations where the public is faced with the placement of a technological object in or close to one's home which is decided about, managed or owned by another;

Socio-political acceptance: involves people's responses to regional, national and international events or policy making, relevant but not necessarily affecting the own situation of the citizens/consumers or their backyard.

While consumer acceptance is characterized by more freedom and control, in the case of citizen acceptance, others generally decide on a certain technology implementation and the amount of public influence on such a decision is uncertain. For instance, in the case of renewable energy, despite the overall positive public acceptance, one could support the same at the community level as long as it is not in their own backyard. Therefore, it is essential, in the context of smart grid development, to further analyze factors influencing citizen acceptance (at community level), such as distributional justice (*How are costs and benefits shared?*), procedural justice (*Is there a fair decision making process giving all relevant stakeholders an opportunity to participate?)* and trust that the community place on the information the intentions of the investors and actors from outside the community (Huijts et al., 2007).

In Figure 12 we summarize the framework within which we consider smart grid development should be approached where the main social elements and soft aspects that will play a key role in the smart grids development are summarized.

5. CONCLUSION AND FUTURE RESEARCH

This report has discussed and presented the different components of the social dimension of smart grid, - consumer, community and society. It has highlighted and discussed the main challenges that surround the development of smart grids. We have based our discussion on the insight from the European smart grid projects. We have proposed a framework of the social dimension of smart grid that should help in approaching smart grid development from a social all-inclusive point of view.

The direction of our future research is to conceptualize a model of the electricity prosumers and to model prosumer behaviours through computational simulation method where, by applying different energy policy and intervention into the virtual environment it is possible to observe and analyse prosumer behaviour when changing different inputs.

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Abstract
Growing concerns over climate change, security of power supply and market competitiveness are challenging the current power system operation and architecture, with the resulting need to integrate increasing shares of renewable and dispersed energy resources. The era of renewable energy, decentralized energy sources and smart grid technologies will empower all prosumers, from households to small and medium sized enterprises, as well as larger companies, to integrate their consumption and production of energy in networks that would function more like ecosystems than markets. The modernization of the grid, with power and data flowing in both directions, to and from the prosumers, will demand and enable new market structures, new services, and new social processes. As a consequence, the most important challenge for policy makers over the next decade will likely be the shift away from a supply-driven perspective, to one that recognizes the need for the integration of the different dimensions and actors of the energy systems. In this context, the aim of the present report is to shed light on the different components of the social dimensions of the smart grids, from the perspective of the consumer, community and society at large, and to highlight and discuss the main challenges that surround it.

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