A Survey Towards Understanding Residential Prosumers in Smart Grid Neighbourhoods

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Abstract—**The smart grid and its promises have sparked world-wide research and demonstration projects, some of which focus on how to empower its users with better tools to monitor, understand, and manage their energy behaviour. It is often seen, however, that the providers of the tools may be driven by a technology push, and hence make assumptions that may fall a short of users' expectations. The lack of understanding on the real-world needs of the users as well as the impact of new technologies and tools may lead to the underestimation or the abandonment of innovative approaches. The issues of how the future smart city residential prosumer will benefit from the future smart grid services and what trade-offs s/he will be willing to make are hot topics. Here, a survey is presented that focuses on these aspects, and especially on the goal of providing new value-added energy services to end-users. An analysis of the survey results and key messages identifies research gaps and proposes promising directions that may be followed when designing applications and services for the residential smart grid prosumers.**

Index Terms—**energy efficiency, energy management, information management, power system economics, privacy, smart grids, social network services**

I. Introduction

THE electric power system is undergoing historical changes [1] as a new paradigm of bidirectional real-time interaction with its stakeholders is now possible. Fuelled by an ageing infrastructure requiring modernization, rising fuel costs, and concerns for the environment, the electric power system is changing in a way that will give producers and consumers (prosumers) more information on and control over their energy behaviour, by allowing them to interact in a fine-grained manner [2]. This is possible due to the rapid advances in the information and communication technologies, which are now amalgamated with an emerging highly distributed energy infrastructure that posses new challenges and also presents new opportunities [3][4].

Smart meters and intelligent sensors and actuators [4] will provide the basis for the information that the stakeholders will have access to, as well as for the additional services as tools that the stakeholders will require in order to manage their energy signature and associated aspects, for example, their costs. This new highly interactive and collaborative infrastructure [5] will enable, for instance, retailers to communicate more effectively with their customers, thus enabling them to take a more active role in the system. The increasing penetration of small-scale generators, such as wind, solar photovoltaic, and micro-CHP technologies in the residential sector, will add yet another degree of complexity for grid-distribution operators and consumers alike. This marks the transition from passive consumers of electrical power, to the "prosumer", which will actively participate in the grid as a possible source of power. With an ever increasing level or intermittent renewable resources in the grid, these new avenues of communication will allow retailers and their consumers to collaborate in order to reduce costs and maximize the utilization of renewable energy, as well as maintain grid stability and improve efficiency through demand response (DR) and demand side management (DSM) programs [6][7].

All these aspects mean a significant change to the way residential consumers will utilize electrical power in the near future. To facilitate the interaction between customers and the grid, new services and tools will be needed, such as real-time and historical access to energy consumption and production, better access to weather information, generation mix, and pricing [8]. Furthermore, value-added services that provide additional benefits and cost savings, such as comparing your usage to that of other similar households in the neighbourhood, or even comparing individual devices with others of the same type, will also be required.

However, although some of these services may seem great on paper, there is no guarantee that they will be used, or even accepted, by their users. Therefore, these services need to be not only identified and designed properly, but also offered in a way that users can easily interact with, and within the scope of the types of behaviours and interactions customers are willing to accept. Therefore, in order for end-users to embrace these services, a good understanding of the needs, background, and required learning curve are necessary, otherwise the services risk being improperly or insufficiently used, abandoned, and may even become a road-blocker for future meaningful efforts to engage the prosumers.

One way to gain some insight into the thoughts and dispositions of the consumers is through focused surveys, which constitute a practical way of gauging stakeholder expectations and inclinations and are routinely performed to this end. While in the process of designing and realising futuristic concepts that allow the prosumers to interact via smart grid services [8], such as trading electricity on a smart-city energy market [9], we have conducted a survey in order to evaluate and understand the interest, impact, and willingness of prosumers. In the next sections of this paper, the survey and its methodology are described (section II), the results and their analysis is presented (section III, and the insights are summarized and discussed (section IV).

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II. Methodology

The results presented here are based on a survey that was conducted in the third quarter of 2011. The main motivation was to better understand residential prosumers and their needs in order to design the necessary applications and services for them within the context of the NOBEL project (www.ict-nobel.eu).

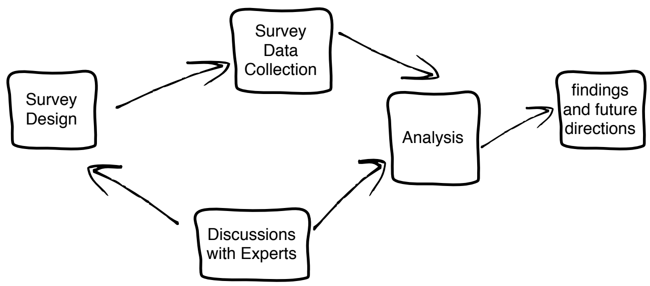

Figure 1. Overview of survey methodology

The overview of the process is depicted in Figure 1, where one can distinguish the following steps. First, we have designed the questions addressed in the survey in order to capture the residential prosumer views from multiple angles. To do so, we have drawn from our experiences with experts and from discussions within EU research projects (that is, SmartHouse/SmartGrid (www.smarthouse-smartgrid.eu) and NOBEL). Additionally, we also considered interactions we had within the scope of several academic conferences, as well as with product groups within SAP. This expertise was used in a dual manner, that is, for the design of the survey as well as later for the analysis of the results and the effort towards their evaluation.

The survey was comprised of 25 questions, of which 19 were yes-or-no questions, 4 were scale questions, 1 was multiple selection, and 1 was a written-response question. The survey was accessible to the public through the NOBEL project's website in both English and Spanish for a period of about 2 months. The questions were targeted at end prosumers of electricity in the residential sector, while no assumptions were made for their background. Aside from demographical questions, such as age, gender, and own assessment on the level of understanding of the subject, the questions were designed to better understand how end consumers felt about hot issues such as privacy, willingness to change their behaviour, the kind of additional information they thought they needed, and the types of energy products and services that they would be willing to engage with in the long run.

The follow-up action was to analyse the results of the survey (as depicted in detail in section III) while drawing to our expertise and interactions as aforementioned. Finally, key findings were identified that are subsequently used for the realisation of services and applications [8].

To provide a better understanding on the pool of survey takers, we mention that these were between 18 and 44 years of age, with a male majority, and mostly European from Spain, Germany, France, and Italy, while a smaller percentage came from other parts of the world such as Egypt and Australia. On average, they considered themselves as having a good understanding of the electrical energy system and of the energy consumption of their devices as depicted in Figure 2. However, based on our experience, many times this view is plasmatic as people generally pay attention to the consumption patterns per device and have a relative good understanding if the consumption is too high or too low, but fail to assess the intermediate levels accurately. Often the estimations are correct for well-known devices such as fridges, but falsely assessed for others such as plasma TVs, stand-by of electric appliances, etc. The need for better quality of information is high and better understanding (mapping to costs) is wished.

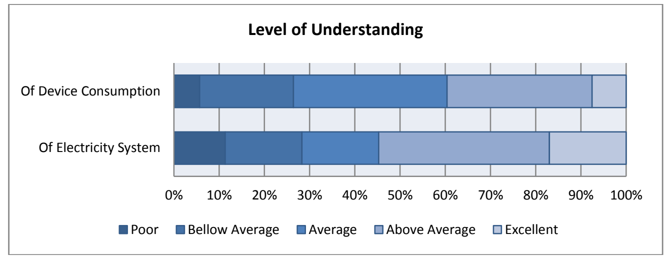

Figure 2. Survey participants' assessment of their energy understanding

III. Survey Analysis

The analysis presented in this section is according to the methodology mentioned, and aims at highlighting the key aspects that were brought to surface. For analysis purposes, the questions were divided into 5 categories: willingness to change, energy monitoring and understanding, automated control, value-added services, and privacy. In the following sections, the results for each category is presented and analysed.

A. Willingness to Change

One of the main pillars upon which the smart grid promise is built assumes that the prosumers are willing to adjust their behaviour based on new timely information they have access to. Although this is a multifaceted problem, it is important to understand if the prosumers want to adjust their behaviour, under what conditions, and in what way. As smart grids envision highly distributed generation, the increased participation of the demand side to stabilize the grid is a highly relevant area of research, as it will greatly impact the way end-users interact with the grid. Understanding the willingness of end-users to transition into this new paradigm of thinking and acting in the smart grid, whether it be responding to price signals, actively trading energy resources, or simply paying a little more to consume more "green" energy, is of paramount importance.

As the nature of the generation and distribution of electricity changes, end-users will have to take a more active role in managing their usage to manage costs and diminish their impact on the environment. Part of the survey questions were pertaining the willingness of the end-consumers to change and adapt their consumption behaviour, to engage with each other to reduce costs, and to provide usage information to

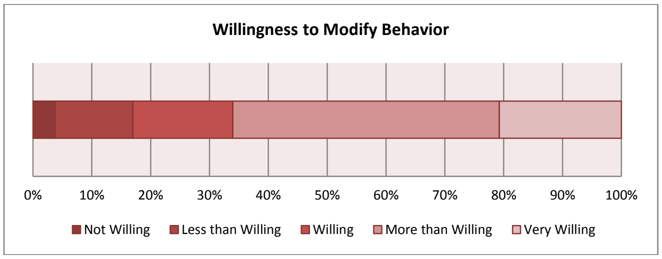

Figure 3. The willingness of participants to modify their consumption behaviour based on external signals such as price.

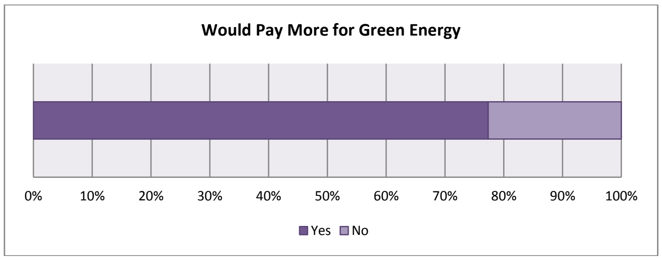

Figure 4. The percentage of participants that would pay more for green energy

their retailer in order to reduce costs. As depicted in Figure 3, depending on the information they acquire, the overwhelming majority of people are willing to modify their own behaviour.

These are some of the key aspects of the smart grid, where people are expected to adjust their behaviour in order to assist reducing energy at peak times, as well as maximize the use of intermittent renewable energy, such as wind of solar photovoltaic. Additionally, the majority of participants would be willing to pay slightly more to reduce environmental impact by using green energy, Figure4. Therefore, in principle the prosumer has an interest in modifying their behaviour; however, to what extent, and by what means, needs to be further investigated.

An interesting aspect in the envisioned smart grid is based on the willingness of "prosumers" to share resources (for example, unused ones) or trade them on an electricity market. The major goal here is the understanding of prosumers' energy behaviour both as individuals as well as part of groups (defined by social, economic, geographic, etc., criteria). The aforementioned objective may be greatly assisted by having better prediction and real-time analytics on the provided and vast smart-grid information. As shown in Figure 5, there is overwhelming support for sharing unused resources, especially if some monetary benefit can be obtained. Additionally, about 2/3 of the prosumers seem positive towards participating in shared-interest groups. This is especially interesting in the cases where service providers may act on behalf of a larger group of users (such as prosumer Virtual Power Plant [7]), and perform actions such as bidding into energy markets [9] or actively managing their participants' energy devices according to bilateral service contracts.

As the smart grid is expected to be information-centric [3], one has to look at the broader picture and not only the technical information that may be acquired by the infrastructure. The increasing trend towards bilateral communication between retailers and their customers means new interaction patterns can emerge, and new approaches in handling dynamic changing situations as required in Demand Side Management and Demand Response can emerge. For instance, customers may reduce their energy costs by providing extra information about themselves, which in turn might help their retailers better assess situations and reduce costs incurred for example by forecasting errors.

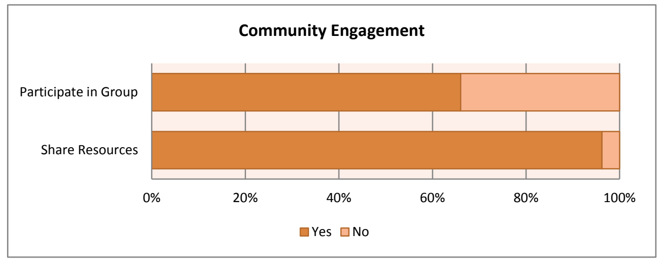

Figure 5. The percentage of participants that would like to engage with their community to form groups and share resources.

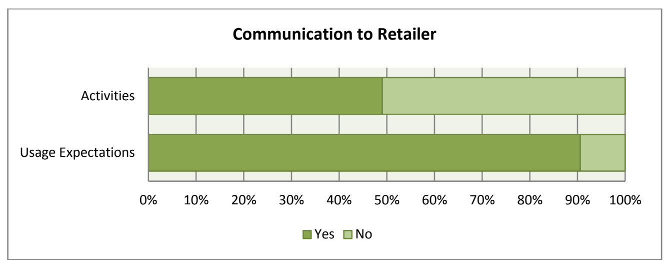

Figure 6. The percentage of participants that would communicate their activities and their usage expectations to their retailer.

The survey results as depicted in Figure 6 reveal that the majority of participants are willing to provide information about their energy-usage expectations to third parties. However, only about half of them are willing to classify in detail their behaviour pattern, for example being on vacation. This seems to suggest that new tools need to be offered to prosumers that allow them to model and understand their energy usage patterns so that they may convey their usage expectations to retailers without revealing detailed, privacy-infringing aspects. Hence, the right balance between privacy and rich user-information provision that the smart grid promises is based upon needs to be striven towards to, and supported by, the necessary tools.

B. *Energy Monitoring and Understanding*

The main argument for the massive roll-out of smart meters has been strongly coupled with the provision of fine-grained information (mostly metering but also other technical aspects) that would enable both retailers and residential end-users to attain a finer insight into their energy consumption and production. This motivation has tangible roots and fits perfectly with the consumer expectations and needs, as depicted in Figure 7, where over 90% of prosumers (i) wish a better information-rich overview of electricity consumption, and (ii) would like to have a better understanding on the impact of individual devices on their energy bill and behaviour. This is a strong case for analytics on the fine-grained energy information that may be generated by the smart grid, and may assist in better understanding of energy impact on the user side. However, this also implies that, apart from the detailed monitoring, the need to be able to either actively enable intelligent devices to communicate their energy behaviour (long-term) [5] or passively deduct it (mid-term), as well as correlation of user-specific context (such as daily tasks) to a workflow of events and the associated energy consumption.

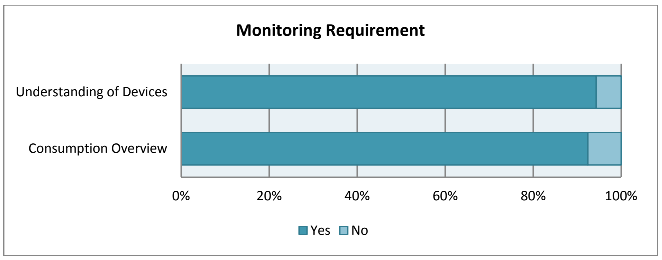

Figure 7. The percentage of participants that would like a better overview of their consumption, or a better understanding of how each device contributes to their usage.

Understanding the need for information that the end-users should be presented with is fundamental in empowering them. To be able to bridge the gap between the information generated on the technical side with a way that can be assessed by the individual user may be subject to several aspects, such as regional, social, economic, etc. From discussions and collected input via the survey, there seems to be a need on a detailed view of the energy consumption by day, and by year, and access to real-time or time-of-use (TOU) pricing. Furthermore, the need for information about the generation mix, weather information, and consumption forecasting was also prevalent, although less so. Some raised the issue of more visibility on how their energy behaviour may impact or comply with larger efforts, such as at local or regional levels, for better energy management and sustainability. Also interestingly enough, over 70% of survey participants showed an interest in comparing their personal behaviour with other energy consumers (such as neighbours or similar households).

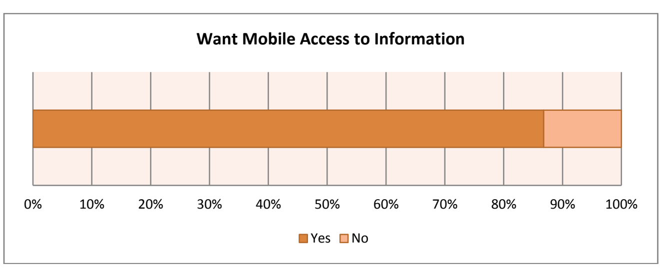

Figure 8. The percentage of participants that would like to access their consumption information from a mobile device.

These findings pose a clear message towards the need to not see the users as individual stand-alone entities but put them in the broader context of a smart neighbourhood and a smart city as well as couple them to ongoing regional and national efforts towards better energy management and sustainability efforts. The latter also implies better visibility of energy policies and their implementation, and could be proven to be a powerful tool for decision makers as well as informed energy-aware citizens of the future.

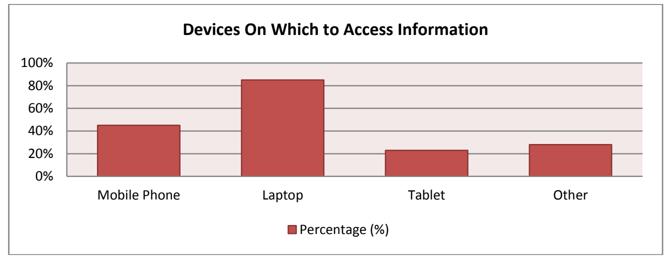

Figure 9. Participant preferred devices (multiple selection).

Having detailed information is key, but the question that arises is how can this be communicated. We have seen the rise of several ideas: monitoring via dedicated in-house appliances, up to anytime, anywhere approaches via mobile phones, etc. The findings of this survey concur as depicted in Figure 8, that the overwhelming majority of users would be interested in monitoring their personal energy consumption from a mobile device, with the highest-rated devices being laptops and mobile phones, followed by tablets and potentially other dedicated ones 9. To our view, this is a clear message that the prime target for providing information to the end-user should not be dedicated (and potentially costly) new devices, but rather re-use existing user devices such as smart phones and laptops, at least in the short and mid term. We can also only estimate that tablets and other devices may rate so low, as users are either not very familiar with them (laptops and smartphones are commodities nowadays), while cost may also be a significant roadblock, especially when it comes down to a dedicated device. For the mid and longer term, other approaches might also be applicable, again by reusing existing infrastructure, for example via smart TVs.

C. Automated Control

Although information-rich real-time monitoring of energy aspects is a key promise of smart grid, in order to be effective this needs to be strongly coupled with real-time control and management of the infrastructure. This will make possible large-scale energy-management approaches such as peak-shaving, as now situations can be monitored and reacted upon in much more sophisticated ways. There are several promising scenarios here,for instance independent service providers would be able to remotely control household devices to curb usage in peaks times. This idea may not be new, as it is already implemented in commercial and industrial sectors, but applying it at large-scale residential areas and infrastructure that could not be monitored and controlled in real-time is new ground. EnerNOC (www.enernoc.com) is a good example of a company offering DR in the commercial and industrial sphere. It bids the energy flexibility of their customers in the energy market; in some cases, its customers can generate more revenue by shutting down machinery to curb energy usage, than by continuing production.

In a more long-term scenario, the devices themselves (or in-house management systems) have access to information, such as prices, and can adapt their behaviour according to the goals of the participant [7], while still maintaining operational and health and safety guidelines. For instance, a smart refrigerator could adapt its cooling cycle to reduce costs, while not adversely affecting the lifetime of the food it contains.

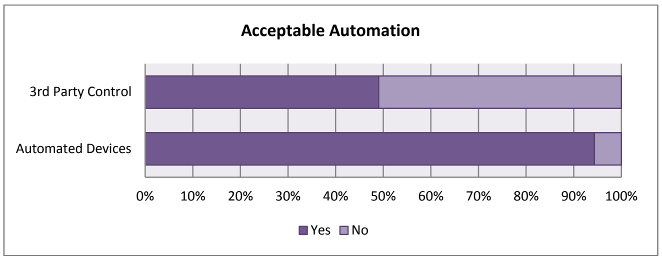

Figure 10. The percentage of participants that would like automates devices and would accept 3rd party management of devices.

Figure 10 depicts that the survey participants are willing to allow automatic management of devices as far as this does not affect any loss of comfort. This open the door for optimisation approaches between usage-patterns and device operation (which may lead to increased energy efficiency), effectively moving away from “one-size-fits-all” design and operational assumptions of appliances towards user-specific adaptations. However, the findings point out that people are more willing to allow their own devices to automate their energy consumption (based on external signals, such as price), than to allow external parties to manage their behaviour. This puts forward a clear message that the user wants to be in control of his own infrastructure but would happily engage to automatic control approaches that do not negatively impact the accommodated lifestyle.

Interestingly, in a follow-up question “If you could trade any excess photovoltaic production in a small market, would you be willing to allow another party to manage that task for you in the same way a managed fund might manage your investments?”, 81% of participants said yes. This seems to indicate a disparity in the willingness to allow third parties control between consumption and production devices. It also suggests that neighbourhood level energy aggregators may be a viable business model for managing local energy requirements in the future. However, this reaction might also be result of inexperience with energy-producing devices and their tight integration with in-house consumption, something that has been fortified with the existing feed-in tariffs in several countries that led to users considering the energy-generation sources as a third-party infrastructure that is just co-located to their premises and hence fail to make the connection between the energy produced by such systems and their own consumption.

D. Value-Added Services

As well as providing end-users with an in-depth view of their energy consumption, fine grained metering data together with artificial intelligence and data-mining algorithms can provide end-users with novel added-value services. Such services are expected to play a pivotal role in retailer offerings, as they might serve as key differentiators between competing stakeholders. Examples of these services could be: enabling end-users to compare their consumption with that of similar households in the region, allowing the retailer to provide their customers with suggestions on how to improve their behaviour, as well as bill shock services (which notify the customer early enough that s/he is on track for a larger than usual bill), or vacation services, which allow the customer to be informed of any unexpected energy usage in the house during a period of absence, such as when travelling. Although innovative creative thinking might come up with new ideas, in order for them to materialize one would have to heavily rely on monitoring, assessment, and management of the infrastructure, its stakeholders, and the information it holds as indicated multiple times in this paper.

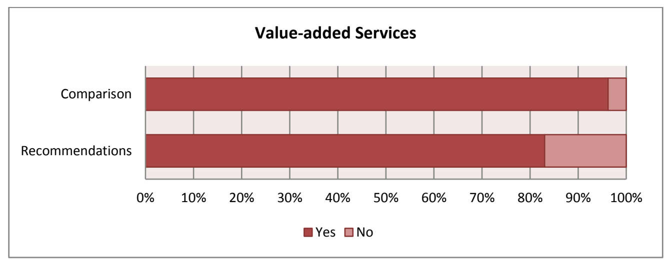

Figure 11. The percentage of participants that would like value added services such as comparison and recommendation.

As can be seen in Figure 11, there is a high level of interest in value-added services such as recommendation and comparison services. In order to catalyse this process, it would be important to outfit consumers with tools that give them access to their consumption data, as well as the ability to manage it, which implies sharing it via user-controlled policy access. With such enabling approaches, innovative on-line services could be created that leverage this data to create value for the customer and the service provider, much in the same way several providers operate today, for instance Facebook and Google in the social media domain.

E. Privacy

Privacy is a key area in the emerging smart grid that needs to be properly addressed in order not to pose as a roadblock. Experience so far both on telecommunications and Internet services has shown that value can be created for the users who may be willingly (or simply unaware of the compromises they get to) sacrifice part of their privacy in order to enjoy such services. Similarly, here the privacy concerns versus the services offered will be a battlefield, and approaches that offer a user-controllable balance between functionality and (private) information provided are sought.

As depicted in Figure 6, the finding is that users may share information and partly trade their privacy if this is done in a controllable visible way, such as sharing data with the energy provider. However, over 90% said that this should be done

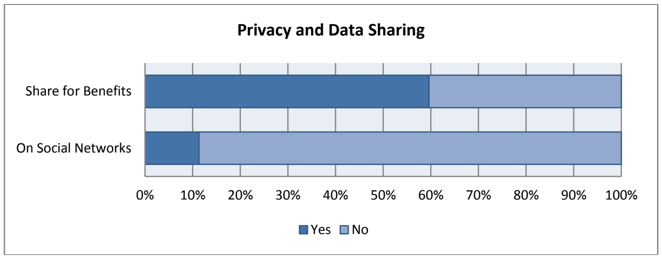

Figure 12. The percentage of participants that would like share their usage information on social networking sites or for additional benefits.

under privacy preserving measures (e.g. anonymization, etc.). This is in line also with the interest in sharing information on social networking sites, for which most of the users do not see the benefit of simply sharing their energy consumption at the moment, probably due to absence of real value-added applications in these. However, this lack of interest dropped to about 50% if additional benefits were given, such as better pricing or access to additional value-added services. Concluding, the finding is that while privacy is paramount, it is still negotiable; however, it is still unclear how much privacy would the participant be willing to sacrifice, and for what level of benefits.

IV. Towards Prosumer Energy Services

The analysis in section III has provided some key messages for the stakeholders actively involved in realising the smart grid. The need to go beyond the fundamentals, that is, smart metering and couple the smart grid with an advanced energy service infrastructure, is eminent. This should not be a standalone one for the sake of the smart grid, but amalgamated with the existing Internet so that existing Internet applications and services can further evolve by taking into account energy information, while the traditional grid processes may also benefit from prosumer interactions at other levels. The latter holds especially true for the three directions dealing with (i) monitoring, (ii) assessment/analytics, and (iii) control, where significant work needs to be invested.

In a more detailed fashion some of the *findings* in the survey point out towards the following:

1) there is a need for better and more fine-grained access to data acquired by monitoring, even down to per device level
2) although there is a need to preserve privacy, there is also the necessity of sharing information and trading part of it in order to enjoy value-added services
3) users are willing to share their energy resources with the local community, in an effort to reduce their own energy costs
4) users would allow third parties to manage and trade their energy resources (solar photovoltaic panels, etc.)
5) think favourably of the idea of smart and self-managed devices, but are unfavourable to third-party direct control of their consumption devices

These findings are in line with the findings from other surveys and reports. For instance in [10], fewer participants seemed interested in obtaining more usage information (in this case through an energy information display (EID)), and also in participating in demand response programs. However this interest is growing [11] and, as our findings indicate, goes beyond simple cost interest towards the community (something that is also verified in [11]). In other surveys [11], the participants did not seem to have a satisfactory understanding of the electricity grid delivery, something that may be depicted also in the results. There is a strong preference to interact via mobile devices while in [10] there is only a smaller (but rapidly increasing) number of users favouring it. Smart appliance usage and participation in energy efficiency actions are in-line with the findings of others [10]. Similar concerns about privacy as well as who controls the appliances are raised [10], which shows that this area needs to be investigated further as it may be a show stopper. It is clear that multi-disciplinary research that goes beyond technology is needed, towards economics and behavioural science [11]. The final success of course is also bound to the specific conditions on user acceptance [12] in each country or region that can stipulate the uptake of the smart grid benefits [13]. Significant effort will need to be invested in modelling the smart-grid prosumer behaviour [14] in order to be able to analyze and correlate it with key performance energy indicators and business scenarios.

An interesting issue is how one should approach these findings, especially from the view of developing new applications and functionalities for the emerging smart grid. The traditional approach in the energy domain is to create monolithic applications, since usually the whole value chain, that is, the data acquisition, analysis, and partially control, were in the hands of the same stakeholder. However, with the liberalisation of the energy market as well as the vision of the smart grid, there are now multiple stakeholders competing in multiple layers. Therefore, integration and interaction based on the traditional models would be not only anachronistic but impossible in the future. The quest then is towards finding commonalities, such as at the functional level, that may be realised by open platforms and services and may provide various views on the acquired data and enable further composition of them to more sophisticated ones. Hence, there is an eminent need [7] for the so called common energy services and data models that can be used as a basis for future developments.

In order to satisfy *finding* 1, services and infrastructure need to be in place to collect the meter readings, assess them in a specific context [15], and make the information accessible in a variety of forms, such as real-time consumption and historical consumption aggregated by day, week, etc. for different time frames. Additionally, they should be offered in a way that a large variety of devices and applications can consume them. In this way, not only will the customers be able to access their information through the web and mobile-phone applications [16], but new devices can be created that leverage this information to help customers manage their energy usage.

Given the participants privacy concerns (*finding* 2), data should be regulated and only accessible by user-allowed stakeholders. However, in order to make more value-added services available, it would be interesting for customers to be able to share their information with third-party service providers (aggregators [17]) in a policy-controlled manner. There are technologies, such as OAuth (http://oauth.net) which can serve as a basis for this type of functionality. While this point is still contentious, because it might go against the interests of the retailer in some situations (such as competitors using the customer data to provide better rates), it can help to accelerate innovation in this area. A significant amount of work will need to be invested in providing not only the right fine-grained access to specific data, but also providing sophisticated capabilities on top, such as anonymization of data, degree of detail to be shared, and even recall of access to data provided to third parties. These, however, call for further significant research and real-world assessment until functional approaches are found and tried-out.

As electricity gets more expensive and technologies improve, the amount of internal generation, at the household level, is likely to rise. This will create new challenges for distribution-grid managers, as the power flow will originate from several points in the distribution grid. This is a big shift from the traditional model where power flowed in one direction. The good news is, at least, that the participants in this survey are willing to share their resources for a cost benefit (*findings* 3,4). Providing a convincing case to the users, especially tackling the aspects of intelligent device control (self o external) and usefulness of having it as part of a broader DR action, is a key area that needs to be addressed [18]. This also indicates that new business models [17][7] and services are required to enable this type of behaviour.

There is already some existing effort in these directions, and as an example we shortly mention the impact on our current work within the NOBEL project that targets to create a secure, robust, and interoperable platform of Internet energy services [8]. The energy services are complemented with mash-up applications targeting grid operators as well as prosumers. Services covering basic functionalities identified in the survey are developed; for instance, metering data collection and monitoring, asset, and user management and billing, as well as added-value services, such user-specific consumption and production prediction. Additionally, to allow consumers to interact and share their energy resources, a local energy-market model was developed and implemented [9]. Services were also developed to allow the customers to trade their energy on the market, as well as for grid operators to manage it. All services are implemented using the REST (REpresentational State Transfer) methodology, which allows them to communicate with any IP-enabled device. This aspect is especially important since it allows the platform to be leveraged from a variety of devices, not only desktops or laptops.

V. Conclusion

As the nature of the electric power grid changes, so will the way customers interact with it. This will bring new opportunities for all stakeholders, as well as challenges. Coupled with the deployment of new infrastructure, such as smart meters, and the increasing importance and penetration of distributed renewable generation, new services and tools will be created to ease the new level of engagement customers will have with the system. In order to target such efforts adequately and in the right direction, this paper has presented the results of a survey directed at electricity end-users. The goal was to understand what types of information and services they would like to have access to, where they would like to access it, and how important privacy was for them. Additionally, the survey tried gauge how willing people would be to engage with their community and share their energy resources.

The major insights analysed in section III and some selected ones outlined in section IV show that customers want a better level of understanding of their behaviour, both in aggregate and at device level. They have concrete preferences for the nature of devices they want to access that information on (mobile ones), which is directly correlated with their comfort zone (low learning curve). It is also shown that the participants are willing to engage with their community and share their production surplus, with an aim to help the community or reduce their overall electricity costs. Furthermore, while the results have re-emphasized the need for strong privacy practices, they have indicated that privacy is negotiable, and that more effort is needed to understand exactly to what extent and in exchange for what. Additionally, methodologies to enable secure fine-grained sharing of data need to be investigated to accelerate innovation in the service space. All in all, the survey has provided useful input for the realization of several energy services [8] within the NOBEL project, which are expected to be evaluated in the real world within the city of Alginet in Spain during the summer of 2012.

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VII. References

[1] SmartGrids European Technology Platform, "Smartgrids: Strategic deployment document for europe's electricity networks of the future," Apr. 2010. [Online]. Available: http://www.smartgrids.eu/documents/SmartGrids_SDD_FINAL_APRIL2010.pdf

[2] M. Franke, D. Rolli, A. Kamper, A. Dietrich, A. Geyer-Schulz, P. Lockemann, H. Schmeck, and C. Weinhardt, "Impacts of Distributed Generation from Virtual Power Plants," in *Proceedings of the 11th Annual International Sustainable Development Research Conference*, Helsinki, Finland, 2005, pp. 1–12.

[3] R. Katz, D. Culler, S. Sanders, S. Alspaugh, Y. Chen, S. Dawson-Haggerty, P. Dutta, M. He, X. Jiang, L. Keys, A. Krioukov, K. Lutz, J. Ortiz, P. Mohan, E. Reutzel, J. Taneja, J. Hsu, and S. Shankar, "An information-centric energy infrastructure: The Berkeley view," *Sustainable Computing: Informatics and Systems*, 2011.

[4] S. Karnouskos, "Cyber-Physical Systems in the SmartGrid," in *IEEE 9th International Conference on Industrial Informatics (INDIN), Lisbon, Portugal*, 26-29 Jul. 2011.

[5] ——, "The cooperative internet of things enabled smart grid," in *Proceedings of the 14th IEEE International Symposium on Consumer Electronics (ISCE2010), Braunschweig, Germany*, 07-10 Jun. 2010.

[6] "Benefits of demand response in electricity markets and recommendations for achieving them." US Department of Energy, Tech. Rep., 2006. [Online]. Available: http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/DOE_Benefits_of_Demand_Response_in_Electricity_Markets_and_Recommendations_for_Achieving_Them_Report_to_Congress.pdf

[7] S. Karnouskos, “Demand side management via prosumer interactions in a smart city energy marketplace,” in *IEEE International Conference on Innovative Smart Grid Technologies (ISGT 2011), Manchester, UK*, Dec. 5–7 2011.

[8] S. Karnouskos, P. Goncalves Da Silva, and D. Ilic, “Energy services for the smart grid city,” in *6th IEEE International Conference on Digital Ecosystem Technologies – Complex Environment Engineering (IEEE DEST-CEE), Campione d'Italia, Italy*, Jun. 2012.

[9] D. Ilic, P. Goncalves Da Silva, S. Karnouskos, and M. Griesemer, “An energy market for trading electricity in smart grid neighbourhoods,” in *6th IEEE International Conference on Digital Ecosystem Technologies – Complex Environment Engineering (IEEE DEST-CEE), Campione d'Italia, Italy*, Jun. 2012.

[10] C. Vyas and B. Gohn, “Smart grid consumer survey preferences and attitudes about smart meters, home energy management, demand response programs, and smart appliances,” PIKE Research, Tech. Rep., 2012.

[11] M. Valocchi and J. Juliano, “Knowledge is power – driving smarter energy usage through consumer education,” IBM Institute for Business Value, Tech. Rep., 2012. [Online]. Available: http://public.dhe.ibm.com/common/ssi/ecm/en/gbe03479usen/GBE03479USEN.PDF

[12] A.-G. Paetz, B. Becker, W. Fichtner, and H. Schmeck, “Shifting electricity demand with smart home technologies – an experimental study on user acceptance,” in *30th USAEE / IAEE North American Conference Online Proceedings*, 2011.

[13] J. Pyrko and S. Darby, “Conditions of energy efficient behaviour – a comparative study between sweden and the uk,” *Energy Efficiency*, vol. 4, pp. 393–408, 2011, 10.1007/s12053-010-9099-x. [Online]. Available: http://dx.doi.org/10.1007/s12053-010-9099-x

[14] I. Lampropoulos, G. Vanalme, and W. Kling, “A methodology for modeling the behavior of electricity prosumers within the smart grid,” in *Innovative Smart Grid Technologies Conference Europe (ISGT Europe), 2010 IEEE PES*, oct. 2010, pp. 1 –8.

[15] S. Ghaemi and G. Brauner, “User behavior and patterns of electricity use for energy saving,” *6. Internationale Energiewirtschaftstagung IEWT*, pp. 1–12, 2009. [Online]. Available: http://www.eeg.tuwien.ac.at/events/iewt/iewt2009/papers/2E_1_GHAEMI_S_P.pdf

[16] M. Weiss, C. Loock, T. Staake, F. Mattern, and E. Fleisch, “Evaluating mobile phones as energy consumption feedback devices,” in *Proceedings of Mobiquitous 2010 (7th International ICST Conference on Mobile and Ubiquitous Systems)*, Sydney, Australia, Dec. 2010.

[17] O. Gulich, “Technological and business challenges of smart grids – aggregator's role in current electricity market,” Master's thesis, Lappeenranta University of Technology, Faculty of Technology, Electrical Engineering, Electricity Market and Power Systems, 2010. [Online]. Available: http://urn.fi/URN:NBN:fi-fe201003041461

[18] J. Stragier, L. Hauttekeete, and L. De Marez, “Introducing smart grids in residential contexts: Consumers' perception of smart household appliances,” in *Innovative Technologies for an Efficient and Reliable Electricity Supply (CITRES), 2010 IEEE Conference on*, sept. 2010, pp. 135 –142.

VIII. Biographies

Per Goncalves Da Silva joined SAP Research in April 2010 as a PhD candidate in the area of Future Energy. Before joining EU NOBEL, he has participated in the EU SmartHouse/SmartGrid project. Prior to joining SAP, he worked as a Java software developer for the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia. He holds a Bachelor of Computer Science (Hons) from Monash University.

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Dejan Ilic joined the SAP Research to contribute to the EU SmartHouse/SmartGrid project, and is also participating to the Industrial PhD program of SAP in conjunction with Karlsruhe Institute of Technology. He currently contributes to EU NOBEL project realization of future energy management in neighbourhoods. He holds a master of science in Information Engineering and bachelor in new Information Technologies.