Integrating prosumers into the electricity grid: the interplays between technology and people

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Abstract

As our energy systems become more decentralized and as the share of small and medium size renewable intermittent sources grows, prosumers become a common phenomenon. The term “prosumers” refers to consumers who can potentially provide valuable prosuming services to the energy system, including not only microgeneration (Megawatts), but also demand reduction (Negawatts), load shifting (Flexiwatts) and energy storage (Storewatts). Smart grids, smart meters, smart appliances and advanced information and communication technologies offer many new opportunities for prosumer-to-grid, prosumer to virtual power plants (VPP) and peer-to-peer energy interactions.

This paper argues that in order to encourage the provisioning of prosuming services (to the grid, VPP or peers) the approaches used to encourage energy saving - such as raising awareness, improving visibility, or promoting pro-environmental values - should be replaced with seamless technologies – i.e., technologies that are nearly invisible to customers or affect them only minimally. These technologies aim to make the provisioning of prosuming services as fully automated, effortless and unnoticed as possible, and include, for example, smart home energy management systems and smart appliances (e.g., IoT). Such technologies could allow continuous interaction between the prosumers and the electricity grid and an ongoing reshaping of demand and supply profiles, which in turn lower energy costs and facilitate the integration of renewables and distributed storage, thus improving the resilience of the system as a whole.

Based on findings from six studies, the paper provides insights regarding the interplay between users and smart technology, and regarding the willingness of potential prosumers to engage in the energy system. Studies suggest that a barrier for energy saving and load shifting is not the lack of awareness but rather the perceived effort required. Findings also indicate that consumers are very willing to allow smart technologies to manage their household energy if their comfort is intact. In addition, studies highlight that smart technologies should be (and equally important - be perceived as) 'user-centric', not only in their friendly user interface, but also in the sense that prosumers need to see how the scheme or technology serves primarily their own interest.

The paper concludes that the smartness of a ‘smart technology’ lies not only in its ability to apply sophisticated means to optimize consumption and performances (a challenge on its own), but also in its ability to differentiate between users, tailoring the most appropriate and suitable engagement option for each one, and thus making them feel that it serves them. Because the technology is invisible, in the mental contract between users and ‘smart technology’ trust plays a crucial role. Hence, the smartness also lies in the technology’s ability to gain prosumers’ trust. This trust is multi-faceted: trust that the technology will not fail or harm them – causing additional hassle and inconvenience; trust that the technology is serving primarily *them* and is aligned to *their* interests, rather than serving the utility or the network manager; and

trust that, when possible, the technology will 'do the right thing' for them and perform socially and environmentally desirable behavior (e.g., saving energy, providing prosuming services).

Critiques of smart technologies argue that the many merits of aware consumption are eliminated when the interactions are made invisible. A possible solution might be periodical reports for prosumers that summarize and make visible the prosuming activities that took place. If such reports highlight the associated social, environmental and financial benefits, they are likely to maintain prosumers' intrinsic and altruistic motivations for engagement, and in addition to further strengthen the trust in the technology. Ideally, prosumers should be actively aware and passively engaged.

Overview

As our energy systems become more decentralized and the share of small and medium size renewable intermittent sources grows, prosumers become a common phenomenon. The term "prosumers" in this paper refers to consumers who can potentially provide valuable services to the energy system, including not only microgeneration (Megawatts), but also demand reduction (Negawatts), load shifting (Flexiwatts) and energy storage (Storewatts). Smart grids, smart meters, smart appliances and advanced information and communication technologies offer many new opportunities for prosumer-to-grid, prosumer to virtual power plants (VPP) and peer-to-peer energy interactions (Parag and Sovacool 2016). How to best integrate, harness and maximize these prosuming services for the benefit of society and the prosumers themselves remains a challenge.

For many years policymakers focused on energy saving and promoted Negawatts via regulation and via raising consumer awareness to their energy consumption. Millions have been invested in developing and installing sophisticated energy monitors and displays, smartphone apps, websites and calculators. Behavioral economic insights, such as consumption comparison to others or to previous consumption, have been widely applied to energy bills. These immense efforts to promote 'behavioral energy efficiency' resulted in various levels of energy savings, many of which were not sustained over time. At the same time, appliance efficiency improved dramatically ('technological energy efficiency') due to regulation and market transformation, resulting in longer lasting yet nearly effortless (behavior-wise) savings. More recently in Europe and elsewhere, millions were invested in promoting small and medium-scale renewable generation - in particular PV cells - initially via Feed-in-Tariffs and later via other arrangements. These investments have led to a growing share of distributed intermittent energy in the electricity network. In the future, it is likely that the provisioning of decentralized Flexiwatts and Storewatts will play a crucial role in preserving the resilience of the energy system and the security of energy services.

I argue that in order to encourage the provisioning of prosuming services (to the grid, VPP or peers) the approaches used to encourage energy saving - such as raising awareness, improving visibility, or promoting pro-environmental values - should be replaced with seamless technologies – i.e., technologies that are nearly invisible to customers or affect them only minimally. These technologies aim to make the provisioning of prosuming services as fully automated, effortless and unnoticed as possible, and include, for example, smart home energy management systems and smart appliances (e.g., IoT). Such technologies

could allow continuous interaction between the prosumers and the electricity grid and an ongoing reshaping of demand and supply profiles, which in turn lower energy costs and facilitate the integration of renewables and distributed storage, thus improving the resilience of the system as a whole.

However, while many smart and seamless technologies are readily available, their wide implementation and integration are contingent upon understanding the interplays between the technology and its users. These interplays consist of various parameters such as perceived effort, perceived demand flexibility, energy practices, trust in technology, trust in institutions, risk perception, values, beliefs and more.

Insights about these interplays and about barriers and opportunities for integrating prosuming services into the electricity system will be illustrated by findings from four studies that took place in Israel between 2013-2017 and by two ongoing field studies in Israel and Europe. Although these studies focus on the Israeli public and context, the insights are of great relevance to other countries searching for policies to promote energy system decarbonization and decentralization via the deployment of intermittent energy resources.

Methodology

The insights presented in this paper are based on findings from the following six published and (as yet) unpublished studies on household electricity consumption that applied various research methods and methodologies[1]:

1. A study of an Israeli rural community (N=68) in which an electricity saving campaign was accompanied by a household electricity metering between June-September 2013. Consumption was compared to that of the same period in previous years (2012 & 2011) (Parag, Zur et al. 2017).
2. A national survey (N=509) of Israelis about perceptions of, and attitudes toward providing prosuming services to the electricity grid (in particular demand reduction, demand response and storage in electric vehicles) (Michaels and Parag 2016).
3. A national survey (N=554) of the Israeli non-technophobic population about interest in automated demand response in the smart home environment (Parag and Butbul 2018).
4. A national survey (N=452) of large Israeli households (4+) that explored the interest in subscribing to Time of Use (ToU) tariffs as a function of the mode of presentation (framing), the discount rate, the perceived demand flexibility and environmental values. (Parag, in preparation).
5. An ongoing research project aiming to reduce summer peak demand via tailored individual nudges and community interventions in two Israeli rural communities (N=350). In this project electricity consumption is monitored via smart meters.
6. An ongoing Horizon2020 funded project (N=43) aiming to reduce household electricity consumption using innovative smart communication in France and Austria (http://www.inbetween-project.eu/).

[1] All the survey samples reported here are of the Jewish population over the age of 21 within Israel. The non-Jewish population (i.e., Muslim, Christian, Druze, and other religious groups), which comprises 20% of the overall Israeli population, is poorly represented by the various existing internet panels and was thus excluded.

Results and findings

Various factors and perceptions influence attitudes toward prosuming, the interest and willingness to participate in energy interaction (i.e., become a prosumer), the acceptability of the enabling technologies and the perceived merits of automation and seamlessness. A recurring theme, however, is that engagement schemes or enabling technologies need to be (and equally important - be perceived as) 'user-centric', not only in their ease of use and friendly user interface, but also in the sense that prosumers need to see how the scheme or technology serves primarily their own interest. 'Own interest' could mean different things for different people - for most it is saving (or earning) money, for some - saving time, reducing hassle and improving comfort, while for others it is accomplishing social desirability (doing the 'right thing'), or gaining other non-energy benefits.

Awareness and effort

Technologies that provide feedback and information and increase consumers' awareness of their energy consumption are already widespread. The alleged effectiveness of such technologies is determined by their ability to raise awareness and provide tailored advice, which ideally lead to more efficient consumption and to environmentally-aware behavior. Michaels and Parag (2016) examined consumer's interest in various types of information that could be provided by such platforms and that could, potentially, help them reduce electricity consumption and 'generate' Negawatts and Flexiwatts. Overall, findings indicate that while people are aware of the environmental benefits of saving energy and shifting demand, they are not particularly interested in actively engaging with their electricity consumption. They would like to receive information about monetary savings that could be made if a specific appliance were turned off, but are not so interested in consumption comparison to others. Similarly, in a survey done for the InBetween project with 33 social housing households in France and 10 households in Austria, results indicate a rather low interest in engaging with personal energy use. All participants mentioned money saving and environmental benefits as their main motivations to save energy, but the preferred information was how much money the household would have saved were a specific appliance switched off or replaced, while information on CO_2 emission was ranked low. In addition, all the participants preferred tailored goal setting over consumption comparison to others. When asked how often they would like to receive the information - the vast majority replied once or twice a month, rather than daily or weekly. In a similar vein, while designing the research in the Israeli rural communities in which tailored text messages are sent to 'heavy users' during summer peak hours with various nudges that encourage energy saving, the community leaders opposed a daily text message, arguing that it will 'annoy' consumers. Two text messages a week was perceived by the community leaders as the maximal acceptable intervention. These findings suggest that people understand the personal and environmental merits of reducing their energy consumption even without being informed about them, and that they are not so keen to engage too often with their consumption. In addition, visibility and awareness are not necessarily perceived as promoters of energy related behavior change, and, over a long period, frequent nudges are likely to be ignored or even counterproductive.

Effortlessness

Parag, Zur et al. (2017) investigated the interlinks between consumers' willingness to save energy, the energy saving economic cost, and the required behavioral effort. Findings reveal that people are aware of the various energy saving behaviors they can perform. However, often even a slight effort to save energy with no associated economic cost - such as changing AC thermostat settings, switching off lights, switching off computers and TV sets while not in use - hinders consumers' willingness to perform them. It is likely that a technology that reduces the perceived effort – i.e., makes these behaviors effortless - has the potential to remove the barrier from providing these Negawatts or Flexiwatts. Essentially, seamless technology provides two benefits to its users: (1) social desirability - their household implements what they perceive as the 'right' behavior (e.g., protecting the environment), and (2) hedonistic value - they save (or earn) money. These benefits are gained effortlessly - without attention or hassle.

Parag (in preparation) investigated the impact of the following on the interest of large households (4 residents or more) in subscribing to a Time of Use (ToU) arrangement: the size of 'off peak' discount, the mode of presentation of information (framing the scheme as a mere 25% or 50% off-peak discount rate versus adding to the discount an altruistic motivation that highlights the contribution of ToU to both GHG emission reduction and Israel's energy security), the perceived flexibility of demand, as well as variables related to values, beliefs and daily energy practices. While the framing and the size of off-peak discount rate did not influence the interest in subscribing to a ToU scheme, the perceived inability to shift the use of appliances (i.e., low demand flexibility) posed a significant obstacle which reduced the interest in subscribing. This was true even for those who reported high pro-environmental values and for those who understood the ToU related environmental and energy security benefits. However, nearly all the participants were very willing to allow an automated system (such as a smart home) to shift the load of their washing machine, drier, dishwasher, heating system and AC from peak to off-peak provided their comfort remains intact. This suggests that people are open to accepting energy management seamless technology. From the energy management point of view – an automated system has the potential to transform some kW into available Flexiwatts.

Parag and Butbul (2018) point at the already existing high level of interest in smart home technology. According to their study, prospective adopters are 'technology optimistic' and value the various perceived benefits of comfort and convenience associated with the smart home technology, as well as the potential economic and environmental benefits related to the energy management function. It therefore seems that at least some Negawatts and Flexiwatts of this segment of society could be readily available to use once the technology is installed.

Trust and self interest

Michaels and Parag (2016) explored whether trust in a range of institutions that currently oversee engagement or will do so in the future (e.g., local and national government or commercial firms; non-profit and for-profit organizations) influences willingness to accept new demand side management schemes and technologies. The findings indicate a low level of trust in all the proposed institutions and organizations.

One facet of this low trust (also demonstrated in Parag, in preparation) is the perception that these institutions aim to serve primarily their own interest rather than that of their consumers, and therefore any arrangement offered by them is likely to be aligned with that self-interest. Indeed, the perceived risk of household data being sold by the managing institution for profit was ranked higher than the risk of privacy loss, and was found to deter people from participating in demand management schemes. However, these risks are perceived differently in the case of smart homes. Parag and Butbul (2018) reveal that while in the case of smart home energy management systems loss of privacy and data sold to a third party are risks that non-technophobic people acknowledge, these risks do not deter users from allowing the smart home to manage their energy use in reaction to price signals, given that they save money and their comfort is intact. It seems that smart home technology is perceived by consumers as 'consumer-centric' – a technology that serves primarily the owner, rather than the utility or the grid operator.

A different type of trust that was investigated is trust in the technology itself. Findings from Michaels and Parag (2016) reveal the widespread concern regarding high levels of harmful radiation emanating from the smart meters themselves. The invisibility of radiation, coupled with low trust in the institution that installs the meter, might hinder installation and as a result reduce engagement options and opportunities. A somewhat related aspect is users' fear that smart technology will alienate them from their home. Indeed, Parag and Butbul (2018) show that amongst the non-technophobic public, negative perceptions of smart homes reduce consumer's willingness to allow it to manage household energy. When offered (in Michaels and Parag, 2016) the option to save money by personally remotely controlling AC, dishwasher and washing machine operation in reaction to a price signal, more than a third (in the case of washing machine and dishwasher) and nearly half (in the case of AC) were not interested and preferred their current situation.

Financial incentive

The above studies, like many others, highlight the impact of economic incentives and economic barriers on the willingness to engage with the energy system and on the perceived ability to generate Negawatts, Flexiwatts or Storewatts. Parag, Zur et al. (2017) and Michaels and Parag (2016) showed that the high cost of energy efficient appliances is perceived as a barrier for saving energy. But Michaels and Parag (2016) also demonstrated the change in willingness to make Flexiwatt and Storewatts available to the system when economic benefits were offered in return. The percentage of people willing to allow the network manager to remotely control appliances in order to improve the network performance increased dramatically (up to three-fold) when financial incentive was offered compared to no incentive at all. Likewise, the willingness to allow the network manager to store and withdraw electricity from Electric Vehicle (EV) batteries increased when financial incentive was offered. Interestingly, the willingness further increased when the incentive was offered as a payment for the service rather than a discount in the EV charging rates.

It is important to note that consumer's willingness to give up control varies between appliances – control over washing machine and dishwasher is given up more easily than control over AC or refrigerator. In addition, the more guarantees offered to prosumers that their level of energy service as well as level of comfort will remain intact, the greater their willingness to participate in the energy system and share their

Flexiwatts and Storewatts. The perception of smart homes as consumer-centric seems to provide a guarantee for its users that their interests is the priority.

Conclusions and implications: actively aware and passively engaged

This paper suggests that smart technologies, such as home automation and IoT, offer consumers an effortless and nearly seamless route to becoming prosumers and engaging in the energy system by providing Negawatts, Flexiwatts and Storewatts. It also suggests that while the strategy of encouraging consumers to save energy or shift demand by eliciting altruistic motivations (e.g., act for the sake of environment) or even hedonistic ones (e.g., save money) could enhance consumers' understanding of these matters, it does not necessarily lead to engagement. That is because lack of motivations is not a barrier, but the perceived associated effort - is. Hence, the seamlessness and effortlessness of 'smart technologies' provide the key for unlocking (at least some of) the prosuming services.

The smartness of a 'smart technology' lies not only in its ability to apply sophisticated means to optimize consumption and performances (a challenge on its own), but also in its ability to differentiate between users, tailoring the most appropriate engagement option for each one and thus making them feel that it is user-centric. Because the technology is invisible, in the mental contract between users and 'smart technology' trust plays a crucial role. Hence, the smartness also lies in the technology's ability to gain prosumers' trust. This trust is multi-faceted: trust that the technology will not fail or harm them – causing additional hassle and inconvenience; trust that the technology is serving primarily *them* and is aligned to *their* interests, rather than serving the utility or the network manager; and trust that, when possible, the technology will 'do the right thing' for them and perform socially and environmentally desirable behavior (e.g., saving energy, providing prosuming services).

Criticizers of smart technologies often refer to them as 'smart wash' and argue that smart technologies lead to 'stupid' people. These critiques highlight the tension between the desire for pro-environmental consumers who deliberately display environmentally and socially aware behavior, and the merits of applying technology to optimize energy management rather than relying on behavior that is hard to predict. The key to achieving the first goal is awareness, visibility and education, while the key to achieving the second is automation as well as relying on commercial companies to provide solutions. These critiques imply that the various merits of awareness are eliminated when the interactions are made invisible. A possible solution might be periodical reports for prosumers that summarize and make visible the prosuming activities that took place. If such reports highlight the associated social, environmental and financial benefits, they are likely to maintain prosumers' intrinsic and altruistic motivations for engagement, and in addition to further strengthen the trust in the technology. Ideally, prosumers should be actively aware and passively engaged.

Regulating smart technology and the prosuming market is crucial for the development of these interlinked sectors. Policy makers at the national level should structure and regulate a fair, transparent, and trusted market for prosuming services. At the international level, they should provide the backbone of technology trustworthiness by creating unified standards for quality, safety and technology compatibility assurances.

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