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The flexible prosumer: Measuring the willingness to co-create distributed flexibility

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ABSTRACT

Rising shares of fluctuating renewables increase the need for flexibility in the power market. At the same time, the emergence of the prosumer has created new opportunities for co-creation of distributed flexibility. As of yet, there is surprisingly little empirical analysis in terms of whether individuals are actually ready to co-create flexibility, and if so, under which conditions these resources can be mobilized by grid operators or electricity supply companies. We address this gap in the energy economics literature with three studies analyzing in total 7′216 individual decisions in a series of choice experiments with 902 study participants in three main domains of residential energy prosumption: (1) solar PV plus storage, (2) electric mobility, (3) heat pumps. We develop a novel measure of the prosumers' willingness to co-create flexibility, and solicit their preferences for power supply contracts with varying levels of flexibility to derive implied discomfort costs. Our results indicate that current and potential electric car and solar PV users exhibit a higher willingness to co-create flexibility than heat pump users. Reaping the potential in those two domains requires taking the prosumer perspective into account when designing policy instruments and creating adequate business models.

1. Introduction

Matching supply and demand over time is a key challenge in power markets. In traditional electricity markets, demand has largely been taken for granted, while the necessary flexibility has been built into the supply side through peak power plants and centralized storage. Increasing shares of fluctuating renewable energies have enhanced the need for flexibility to avoid imbalances in the power system. Established and new companies develop novel business models to provide flexibility (Helms et al., 2016). Decentralization trends in the energy market offer new opportunities for matching supply and demand in a distributed manner. Distributed flexibility provision can take different forms: Shifting demand and supply over time and/or building up local storage capacity. Successfully mobilizing flexibility in distribution grids can help to delay or avoid investments in extending centralized grid infrastructure (Gordijn and Akkermans, 2007; Veldman et al., 2013), resulting in cost efficient energy systems and allowing smooth integration of renewables (Denholm and Hand, 2011). While centralized sources of flexibility (e.g. gas-fired power plants or hydropower reservoirs) are well understood, the tendency of decentralized electricity consumers becoming prosumers (producers and consumers at the same time, cf. (Bergman and Eyre, 2011; Kotler, 1986; Toffler, 1980)) provides a potentially valuable source of – so far underutilized – flexibility (Gordijn and Akkermans, 2007; Kubli, 2017; Veldman et al., 2013). Decentral prosumers can provide flexibility by optimizing the timing of their electricity production and consumption, and by making decentralized storage available (e.g. through investing in batteries or providing heat reserves through a more flexible heating behavior). A better understanding of whether and under which conditions prosumers are actually ready to contribute to flexibility provision is important if these resources are to be mobilized.

This paper empirically investigates prosumers' willingness to co-create flexibility with a series of studies across three main domains of energy use: (a) solar PV plus storage, (b) electric vehicles, (c) heat pumps. By conducting three choice experiments with a unique sample of actual and potential flexible prosumers in Switzerland (N = 902), we aim to answer the following two research questions:

1. To what extent are prosumers willing to co-create flexibility?
2. Are there differences between the three technology domains?

Our paper makes three main contributions to the extant literature on smart grids and flexibility in the power market. First, we answer the call for "putting people in the loop" (e.g. Sowe et al., 2016) and for

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revealing determinants of social acceptance of smart grids (Wolsink, 2012), by investigating the preferences of end users as important agents in the diffusion of distributed flexibility. Second, we develop an innovative way of operationalizing and measuring the willingness to co-create flexibility. Third, we provide a pilot application of this measurement instrument that can serve as a role model for policymakers and energy companies who seek to effectively engage prosumers.

This paper is structured as follows. In the second section, we discuss existing literature on distributed generation, energy consumer preferences, and the role of prosumers in co-creating flexibility. In the third section, we introduce our methodological approach. Section 4 presents the results of the three studies and a discussion, while Section 5 concludes the paper with implications for energy policy and flexibility business model design, as well as a section on limitations and further research.

2. Literature review

2.1. Energy system flexibility and smart grids

As Lund et al. (2015) point out, energy system flexibility is "definitely a 'hot topic'". Their review of close to 400 academic publications presents a comprehensive overview of all the available options to integrate increasing shares of renewables in the grid, from large-scale centralized to small-scale decentralized, from supply-side to demand-side, and across a range of different time horizons. As another indication of the "hot" nature of this topic, the European Commission under its Horizon 2020 research programme is currently investing 337 million Euros of R&D funding in projects related to accelerating smart grids and storage deployment.[1] While there is an increased understanding of the large technical potential of distributed flexibility, previous attempts to assess the market potential are handicapped by the lack of reasonably fine-grained empirical data (Kondziella and Bruckner, 2016). This is particularly true for the emergence of decentralized battery storage, which could potentially revolutionize the power market (Agnew and Dargusch, 2015; Ebers and Wüstenhagen, 2015; Kubli, 2017), but are still in a nascent stage of market development. As a result, there is currently a wave of search processes for viable business models to deploy distributed flexibility options like demand response, energy management systems, electricity and thermal storage, and distributed solar photovoltaics (Burger and Luke, 2017). While both the need for and the potential of distributed flexibility options are now widely acknowledged, whether or not business models in this realm will be economically viable ultimately depends on whether they create customer value. This is increasingly understood by policymakers and business model developers, as evidenced for example by the creation of a Working Group on customer engagement in the above-mentioned EU initiative.[2] The following section contributes to this debate by offering a structured review of starting points for investigating prosumer preferences for flexibility co-creation.

2.2. Consumer preferences for electricity, demand response and the rise of the prosumer

The literature on preferences of energy consumers has gradually evolved from the traditional view of taking demand as given towards including aspects of flexibility and the rise of the prosumer (Fig. 1).

Traditional studies investigating consumer preferences have focused on explaining consumer choice in liberalized electricity markets, determining the role of factors like price and contract duration (Burkhalter et al., 2009). It was found that switching behavior has remained below expectations in many markets, pointing to the nature of electricity as a low involvement product and the strong role of routines and inertia in electricity consumer behavior (Herbes and Friege, 2017).

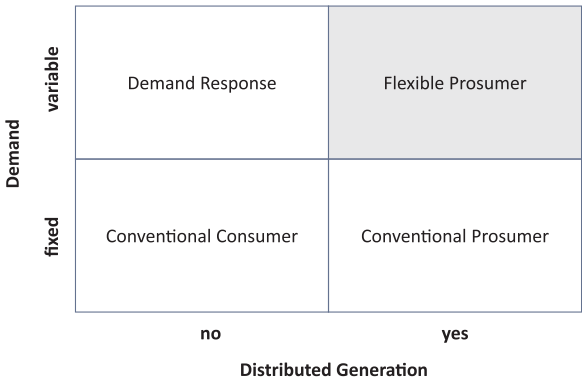

Fig. 1. From conventional consumer preferences towards flexible prosumers.

One factor that has been found to be relevant is the electricity mix, in that offering electricity products with a high share of renewables can be a way to overcome customer inertia (Kaenzig et al., 2013; Roe et al., 2001; Tabi et al., 2014). By measuring respondents' stated preferences, these studies provide insights into consumers' willingness to pay for changes in the attributes of electricity products.

A second stream of research looks at consumers' willingness to participate in demand response programmes, i.e. to allow utilities to shift some of their demand in time (Cappers et al., 2010; Torriti et al., 2010), to develop consumer segment-specific product and service offerings (Kaufmann et al., 2013) or to advance detailed understanding of personal traits as drivers of consumer acceptance of smart grids (Gamma, 2016) such as for instance perceived control over appliances (Moser, 2017). A common finding is that consumers request a relatively high financial incentive in order to voluntarily sign up for demand response programmes, and the likelihood of participation increases if required changes in daily routines are minimized (Annala, 2015). Apart from stated preference surveys, there are also some analyses of revealed preferences, for example tracking the behavior of participants in pilot programmes (e.g. Wemyss et al., 2016). A common finding of these studies is that the individual and societal advantages of participating in a demand-response program are not obvious to consumers, unless they actually get a chance to experience what this implies in everyday life (Dütschke and Paetz, 2013). Paterakis et al. (2017) even conclude that "the greatest challenge is related to the successful engagement of customers in demand response programmes", illustrating the need for further research on end-user preferences.

A third stream of research, represented by the lower right quadrant in Fig. 1, investigates what makes consumers become actively engaged in their energy supply, i.e. to become prosumers. A popular theme here is to explore determinants of homeowners' decision to install solar photovoltaics on their roof (Curtius et al., 2017; Rai and Robinson, 2013; Sigrin et al., 2015). There is mixed evidence on the role of traditional socio-demographic factors like income, education and environmental awareness (for a review, see Dharshing, 2017). In contrast, preferences for independence and peer effects have been shown to be effective drivers of installing solar PV (Bollinger and Gillingham, 2012; Dharshing, 2017; Kubli, 2017; Kubli and Ulli-Beer, 2016; Rode and Weber, 2016).

The fourth quadrant in Fig. 1 represents the logical combination of quadrants two and three, namely prosumers actively engaging in flexibility provision. Such flexible prosumers go beyond the electricity production activities of conventional prosumers (which for instance, install a solar photovoltaic system on their roof and feed the electricity into the grid). Flexible prosumers in turn co-create flexibility by different means. A well-known example is demand response and the flexible timing of consumption (e.g. through smart appliances, smart heat pumps or smart charging of batteries). However, also the production of electricity can now be flexible, as for instance PV-battery systems allow prosumers to be more flexible in regard to when to feed electricity into the grid. Also novel heating systems facilitate the

[1] http://www.h2020-bridge.eu/wp-content/uploads/2017/06/BRIDGE_presentation_EUSEW17.pdf.

[2] http://www.h2020-bridge.eu/working-groups/customer-engagement/.