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Sharing electricity storage at the community level: An empirical analysis of potential business models and barriers

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ABSTRACT

More and more households are installing residential electricity storage systems to increase the self-consumption of electricity they produced. Some governments have accelerated this development through specific financial support schemes to offset the costs, which still remain high. Compared to the use of single-household systems, the sharing of mid-scale electricity storage systems in neighborhoods could reduce the Levelized Costs of Storage (LCOS). However, a model for the shared usage of storage by multiple households has yet to emerge. We investigated eight demonstration projects in Germany and Western Australia with capacities between 100 and 1100 kW h with respect to potential business models and barriers in a cross-case study based on document analyses and expert interviews. We found that models relying on the transmission of electricity from individual rooftop photovoltaics to a shared storage system through the public grid are facing significant regulatory barriers. Removing these policy barriers would enable a more efficient use of electricity storage systems. By contrast, projects relying on a less regulated microgrid managed by the administration or strata entities of multi-household developments already seem promising under the current regulatory framework.

1. Emergence and integration of electricity storage systems

The strong global momentum towards renewable energy will, in all likelihood, increase the important role of photovoltaics (PV) and wind power (Obama, 2017). With increasing shares, however, the intermittency of renewable energies will become progressively problematic. The impact of fluctuating power generation on electricity systems as a whole is increasingly recognized on an international level (International Energy Agency, 2014). Backup capacities such as grid extension or storage can help to meet load requirements for high shares of intermittent renewable energy (Steinke et al., 2013). Electricity storage is an important technology option if further cost degressions can be achieved (Braff et al., 2016). While it has been debated whether there is a need for electricity storage in the short term (Fürstenwerth and Waldmann, 2014; Schill, 2014), battery storage coupled to residential PV, in particular, is gaining considerable traction and is therefore likely to play a significant role in the transition (Agnew and Dargusch, 2015). Recent studies on patent applications in electrochemical electricity storage technologies support this reasoning (Golembiewski et al., 2015; Mueller et al., 2015). Many private and public laboratories undertake significant efforts to optimize battery chemistries (e.g., Larcher and Tarascon, 2015; Lin et al., 2017), as well as battery (e.g., Campestrini et al., 2016; Hannan et al., 2017) and energy (e.g., Olatomiwa et al., 2016; Thien et al., 2017) management systems. These advances are also supported by demand from the electric vehicle industry, where module costs have come down significantly in recent years (Nykvist and Nilsson, 2015). Further cost reductions are expected due to learning effects and economies of scale (Kittner et al., 2017; Schmidt et al., 2017). Technological progress gives policymakers choices regarding type, distribution, and support of electricity storage systems. To avoid the lock-in to suboptimal solutions, however, an early and careful studying of policy design is required.

Indeed, Fares and Webber (2017) showed that residential storage, a currently evolving market segment, can lead to overall increased emissions due to inefficiencies. At the same time, studies show that a combination of multiple applications (He et al., 2011; Lombardi and Schwabe, 2017; Stephan et al., 2016) or the sharing of systems by multiple users (Parra et al., 2015, 2017) would increase the (cost) effectiveness of electricity storage systems. To date, there is only little insight how the sharing between users or applications could be combined to business models and what barriers pilot projects in this area are facing. We sought to fill this gap by conducting a cross-case study on current demonstration projects in Germany and Western Australia.

The remainder of this paper is organized as follows: The following section reviews the essential theoretical background. Section 3 describes materials and methods. Section 4 gives a brief overview of the

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cases. Section 5 presents the results of the cross-case analysis, i.e., key design possibilities, barriers and exemplary models. Finally, Section 6 gives conclusions and discusses the policy implications of our findings.

2. Theoretical background

2.1. Strategic Niche Management, business models and the role of demonstration projects

A progressive change from the traditional centralized power generation to a decentralized system with intermittent renewables and storage would constitute a regime change. The socio-technical systems literature describes how changes from one socio-technical regime to another can occur (Geels, 2004). In general, socio-technical systems are stable towards small variations and can, therefore, be inert to change. Prototypes of new regime archetypes can, however, be formed in niches (Geels, 2004). The bud of new regimes are niches, whose growth can eventually lead to regime change. Strategic Niche Management (Kemp et al., 1998) has been developed as a tool to foster such niches and help to achieve the regime change towards sustainable developments. Recently, the ‘business model’ concept has received increased attention within the Strategic Niche Management literature (Huijben and Verbong, 2013), as business models are necessary for the upscaling of novel technologies (Johnson and Suskewicz, 2009). Business models are part of the knowledge creation and formation of niches towards a “dominant design” (Geels, 2011). Recently, Bolton and Hannon (2016) also highlighted the role of business models within socio-technical systems for governing change.

While there are several business model definitions (Massa et al., 2016), the one of Osterwalder (2004); (Osterwalder and Pigneur, 2010) is rather established within the energy policy area (Engelken et al., 2016; Hall and Roelich, 2016; Hannon et al., 2013; Huijben and Verbong, 2013). At the highest level, the definition can be considered as quadripartite, consisting of “value proposition”, “customer interface”, “infrastructure”, and the “revenue model” (Richter, 2012). On a more detailed level, the customer interface can be further divided into “customer segments”, “channels”, and “customer relationships”. The infrastructure consists of “key resources”, “key activities”, and “key partnerships”. Within the revenue model, “revenue streams”, and “cost structure” can be distinguished (Richter, 2012).

Pilot projects play a major role in the development of new business models. This is particularly the case in technology developments (Hellsmark et al., 2016). In fact, many new commercial activities of firms have their origin in projects (Shenhar and Dvir, 2007). Bohnsack et al. (2014), for example, empirically showed how business models for electric vehicles developed out of initial projects. Nevertheless, the study of projects is not only important for practitioners or researchers working on the firm's perspective. Projects play a significant role in the creation and evolution of niches (Schot and Geels, 2008) and can thus be the very starting point of socio-technical transitions. Of equal importance is the fact that practice-based action research is a crucial pillar to ground the mathematical modeling of systems and socio-technical analyses (Geels et al., 2016). In this context, practice-based action research has several merits according to Geels et al. (2016): First, it highlights the role of stakeholder alliances, second, it can unlock drivers beyond mere financial incentives and third, it offers the opportunity for optimization by experimentation. Consequently, Geels et al. (2016) argue that practice-based action research can give valuable feedback to quantitative simulations and socio-technical analyses, which in turn can provide insights on where new demonstration projects are most useful. In fact, in a socio-technical analysis on electricity storage, Grünewald et al. (2012) called for demonstration projects in niche applications to avoid the lock-in to other technologies, because electricity storage is currently facing several institutional and regulatory barriers.

2.2. Electricity storage applications and retail electricity prices in Germany and Western Australia

By reconfiguring the value chain, the notions of the value propositions developed in the traditional centralized system blur, particularly when multiple prosumers are involved. Thus, Hall and Roelich (2016) defined the notion of “complex value” as “the production of financial, developmental, social and environmental benefits which accrue to different parties, across multiple spaces and times, and through several systems.” This concept is particularly relevant in the context of electricity storage systems, which can have numerous applications. At the generation level, storage can help to restart conventional generation assets in the absence of power from the grid and also shape the output profile of renewable energy sources (Battke and Schmidt, 2015). The Levelized Costs of Energy (LCOE) of a renewable energy source (Kost et al., 2013), combined with the Levelized Costs of Storage (LCOS) of a battery (Jülch, 2016), are in many cases higher than the wholesale electricity prices of mainland grids in industrialized nations (IEA, 2017). However, a renewable energy source combined with a battery is competitive in remote regions and islands where the alternative would be a diesel generator (Blechinger et al., 2016). At the grid level, electricity storage can be used to hold voltages and frequencies in a district within the specified limits and can provide “reserve capacity,” “transmission & distribution investment deferral,” and “wholesale arbitrage” (Battke and Schmidt, 2015). At the consumption level, storage can increase “end-consumer power quality,” “end-consumer power reliability,” “self-consumption,” and can be used for “end-consumer arbitrage” (Battke and Schmidt, 2015). Numerous studies have analyzed and compared the profitability of the aforementioned value propositions (e.g., Battke et al., 2013; Braff et al., 2016; Eyer and Corey, 2010; Fitzgerald et al., 2015). The “increase of self-consumption,” “end-consumer arbitrage,” “grid investment deferral,” primary, (negative) secondary or (negative) tertiary “reserve capacity” are particularly prominent value propositions when considering both practical implementation and economic viability (Stephan et al., 2016). Recent studies have also shown that a combination of value propositions can benefit overall profitability (Fitzgerald et al., 2015; Stephan et al., 2016).

Many residential PV plus storage systems serve to increase self-consumption. In this application, energy produced on site is stored for subsequent use. This can happen for financial, psychological or ecological motives. In the increase of self-consumption, the system competes with the grid supply and thus retail electricity prices. Germany and Australia are among the countries with the highest retail electricity price increases in recent years (Simshauser, 2016). At the same time, both have seen a tremendous uptake in PV over the past years. In 2012, Germany was the leading country regarding PV capacity per capita and Australia the leading non-EU country (Sahu, 2015). At the end of 2015, there were at least 1.6 million PV installations in Germany (Netztransparenz.de, 2016). Australia had 1.6 million small-scale installations by the end of 2016 (Clean Energy Regulator, 2017). Germany's and Australia's storage markets are therefore particularly attractive (Rubel et al., 2017). Of all the major Australian cities, Perth in Western Australia has the lowest Levelized Costs of Energy (Australian Energy Council, 2016), making PV plus storage particularly attractive there. Fig. 1 shows the retail electricity prices in Germany and Western Australia compared to the LCOS and LCOE estimate for photovoltaics. In Germany, the tax percentage in household electricity prices is the second highest of all IEA member countries. In the second quarter of 2016, 53.3% of household electricity prices were taxes (IEA, 2017). Only Denmark had a higher share (58.5%) in this period (IEA, 2017). As can be seen in Fig. 1, a significant fraction is due to the Renewable Energy Act (EEG) apportionment, which finances the feed-in compensation of qualified distributed renewable generators. Besides the generation costs of 7.35 €ct/kW h, other important components are the VAT (19% or 4.76 €ct/kW h), the electricity tax (~ 2.05 €ct/kW h), the