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What hampers energy system transformations? The case of smart grids

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HIGHLIGHTS

- Fourteen in-depth expert interviews were conducted and qualitatively analysed.
- We provide a dynamic smart grid definition framework.
- We examine barriers to smart grid technology implementation.
- We provide recommendations to overcome these barriers.

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ABSTRACT

Energy systems are undergoing significant change. Many countries have ambitions to increase the share of renewable energy in their energy mix. This development entails the challenge of incorporating an increasing amount of volatile energy supply and a higher number of energy providers on distribution grid level. The smart grid could be a solution for this challenge. However, the implementation of smart grid technologies is rather slow. In this paper, we examine which barriers exist for the implementation of smart grid technologies. Fourteen in-depth expert interviews were conducted and qualitatively analysed using the grounded theory approach. First, a dynamic definition framework of the term “smart grid” was developed that incorporates contextual factors. Second, barriers to the implementation of smart grid technologies were gathered. We identified (1) cost and benefit, (2) knowledge, and (3) institutional mechanisms as barrier categories. Third, policy implications were derived. We recommend (1) the acceptance of a diversity of solutions, (2) the acceptance of incremental change, (3) the implementation of a stable regulatory framework, (4) the alignment of interests of individual market participants with the entire system, (5) the definition of a suitable scope of regulations, and (6) the collection of problem-specific information.

1. Introduction

Energy systems are undergoing significant change. The call for renewable energy has triggered two major developments. First, there will be an increasing amount of volatile energy supply (Kranz et al., 2010:1; Wissner, 2011b:2510; ZVEI, 2012:3). Second, the number of energy providers on the distribution grid level will increase (Mattern et al., 2010:2; Verbong et al., 2013:119; Wissner, 2011b:2509). Both of these developments are challenges that can put the stability of energy transportation systems at risk (Verbong et al., 2013:119; World Economic Forum, 2010:12). A solution for these challenges is the implementation of smart grid (SG) technologies to match supply and demand (Kranz et al., 2010:1; Mah et al., 2012b:133; Verbong et al., 2013:117–119).

Changing environments demand organisations to adapt to new circumstances to remain competitive (Pool and Van den Ven, 2004). The case of SGs is particularly interesting because they are praised as a solution for the above mentioned challenges. However, the implementation of SGs is rather slow (Römer et al., 2012:487). From our literature research, the most relevant stakeholders for the development of SGs were derived. These are (1) policy-makers, (2) smart grid technology providers, (3) distribution grid operators (DGOs), and (4) end users (e.g. World Economic Forum, 2010:42–44). We subsumed the regulation authority under policy-makers since their positions are largely identical with those from governmental institutions. The stakeholder DGO also comprises metering service providers and metering point operators. End users include market participants that only consume, only provide, or consume and provide energy, i.e. consumers, providers, and prosumers. In this

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paper, barriers are defined as disruptive factors “that may decelerate, slow down or even block” (Günther and Scheibe, 2006:63) the implementation of technologies. In fact, change processes are likely to entail barriers (Argyris, 1993:31–35; Battilana and Casciaro, 2013:819; Post and Altma, 1994:66–69; Schimmel and Muntslag, 2009:399–400). An analysis of general barriers to change is not sufficient in the case of SGs because barriers are context-specific (Arvanitis and M’henni, 2010:237; Blindenbach-Driessen and van den Ende, 2006:545; Fagerberg et al., 2012:1177–1178; Wu, 2012:489–490), and the energy industry faces distinct challenges. First, with an increasing amount of required information and communication technology, the traditionally long-term oriented energy distribution sector (Cook et al., 2012:4–6; Cramton and Ockenfels, 2012:115) is being confronted with much shorter innovation cycles (Eschenbaecher and Graser, 2011:374). Second, energy grids are traditionally geared to cost effectiveness while at the same time grid operators are now expected to implement innovations (Wissner, 2011b:2516). Third, the design of an energy system is heavily influenced by political decisions (Buhl and Weinhold, 2012:179; Pollitt, 2008:706). However, previous literature is rather fragmented, i.e. limited to certain stakeholders, and does not include a comprehensive analysis of barriers.

We face the additional challenge that no universal vision of a SG exists. For example, the German Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway made an implicit attempt to define smart grid by a division between smart grid and smart market (Bundesnetzagentur, 2011:11–14). Whilst this definition provides a rough distinction between the capacity of an energy grid (in kW) and the market (in kW/h), the actual characteristics of the hardware can be manifold. This problem has been approached with different ways of defining a SG. However, these approaches are often static and do not take into consideration the uncertainties regarding the characteristics of the future energy system which, in turn, influence the design of SGs.

From the two above mentioned research gaps, we derived corresponding research questions (RQs). First, uncertainty about the future energy system is omitted in the SG definitions. Hence, RQ1: “How can the term smart grid be defined?” was formulated. Second, no detailed analysis of barriers to SG technology implementation was identified in the previous literature. Thus, two research questions were derived to inquire into this topic. RQ2.1: “Which barriers exist for the implementation of SG technologies?” addresses the barriers for SG technology implementation. We also investigated recommendations to overcome these barriers with RQ2.2: “How can barriers to the implementation of SG technologies be overcome?”

This study is structured as follows: In Section 2, we provide an outline of the empirical basis of this study and our research approach. In Section 3, we present the results of the expert interviews. In Section 4, we discuss the findings of our analysis and compare them to the findings of existing literature. In Section 5, we present the conclusions of our analysis, implications for policy-makers, limitations of our study and potential for future research.

2. Material and methods

Theory building from case studies is an adequate research procedure (Eisenhardt, 1989:534; Mayring, 2002:41–46; Yin, 2009:5–14) for the case of the barriers to SG technology implementation. This approach has already been applied in the investigation of other SG related issues (e.g. Mah et al., 2012b:134; Römer et al., 2012:489; Wissner, 2011b:2510). Grounded theory hereby forms a suitable and well-tested collection of research methods whose goal is to generate abstract concepts and postulates from primarily descriptive representations of social phenomena (Strauss and Corbin, 2008:50–53).

Because the focus for this study laid on the generation of qualitative data that can be the basis for following quantitative analyses, experts were selected using theoretical sampling (Eisenhardt, 1989:537; Matus et al., 2012:10893; Sandelowski, 1995:180). We chose experts evenly from the fields of (1) research, (2) industry, and (3) associations and political institutions. Following the same approach, the covering of extreme positions (Pettigrew, 1990:275–276) has been considered. In the selection of experts, an advocacy coalition approach (Sabatier, 1998) was used to identify experts with diverging schools of thought in each field. Table 1 provides an overview of the experts and their professional backgrounds. We conducted interviews until theoretical saturation (Sandelowski, 1995:181; Strauss and Corbin, 2008:263) was reached. In this paper, information from interviews is referred to by the number (#*n*) in the left column. Fourteen in-depth expert interviews were performed, either personally or via telephone, by two interviewers between April and August 2013. For this study, we selected one country of origin to avoid biases due to different legal backgrounds; a German context was ultimately chosen because the nuclear phase out and high amount of renewable energy make it an eminent case. We refer to Römer et al. (2012:486) in their argument that such results can provide valuable insight for other countries.

The interviews were conducted on the basis of a semi-structured interview guide. Because different approaches to defining SGs could be identified during the literature research, no working definition was provided to the interviewees in advance. In accordance with established research approaches, the interview contained three predefined research topics (Eisenhardt, 1989:536). First, the influence of different energy system transition pathways on the energy system design was derived from previous research. The validity of this construct for the case of SGs was critically inquired into during the interviews. Second, barriers to SG technology implementation were collected. Third, recommendations to overcome these barriers were gathered. Open questions were formulated to obtain unbiased answers (Reja et al., 2003: 174). The guide was validated using a double cognitive pre-test, i.e. paraphrasing and think aloud interviewing (Collins, 2003) with experts from each chosen field.

Table 1
Overview of experts.

	Research	Industry	Associations and political institutions	Background
#01	✓			Power engineering
#02	✓			Power technology and economics
#03	✓			Energy markets
#04	✓			Information and communication technology
#05		✓		Business development
#06		✓		Chief Executive Officer of SG technology provider
#07		✓		Sales
#08		✓		Communications
#09		✓	(✓)	SG division
#10		(✓)	✓	Power engineering
#11			✓	Energy systems
#12			✓	Energy technology
#13			✓	Energy systems
#14			✓	Energy sector
Total	**4**	**5**	**5**	

Note: More specific descriptions of expert backgrounds are not shown to ensure anonymity.