Utilities Policy xxx (2016) 1–8

Contents lists available at ScienceDirect

Utilities Policy

journal homepage: www.elsevier.com/locate/jup

Typology of centralised and decentralised visions for electricity infrastructure

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ARTICLE INFO

Article history:
Received 26 June 2014
Received in revised form
22 March 2016
Accepted 22 March 2016
Available online xxx

Keywords:
Decentralisation
Centralisation
Electricity infrastructure
Visions

ABSTRACT

Scientific and public controversies about the design of future electricity systems can be observed, including differences around centralised and decentralised approaches. Taking the German case as an example, we develop a typology of (de)centralisation that distinguishes between (1) infrastructure location (connectivity and proximity), and (2) infrastructure operation (flexibility and controllability). This typology is applied to two competing visions for the future of electricity infrastructure. A differentiated view of the various dimensions can contribute to the current debate, clarify visions for development paths, and inform infrastructure governance.

1. Introduction

Scientific and public controversies concerning centralisation or decentralisation can be observed in various utility sectors (Konrad et al., 2008; Truffer et al., 2008). Techno-economic advantages and disadvantages of centralisation and decentralisation (from here on: (de)centralisation) and the governance processes shaping the potential system transformation are at the centre of these debates. This contribution focuses on the techno-economic dimensions of the electricity infrastructure. On the pathway to a cleaner and more sustainable electricity system, increasing amounts of renewable energy sources for electricity (RES-E) generation have been introduced in many countries in recent years. Rising capacities of RES-E power plants with variable output, such as wind turbines or photovoltaic systems, affect and potentially transform the entire electricity system, as can be seen in countries such as Germany and Denmark (Lund et al., 2012). We take Germany as an example, where RES-E generation has strongly increased in recent years and in 2014 reached a share of almost 28 percent in the electricity mix (BMWi, 2015). Concerning the future development of the electricity system, a consensus seems to exist among most actors in Germany that RES-E technologies will become the primary source for generation. The strongest disagreements can be found with regard to the time needed for this shift and the actual design of the RES-E system, which includes the question of whether the infrastructure should be centralised or decentralised.

Transition scholars define the electricity system as a socio-technical system that not only consists of the physical infrastructure but that is also strongly influenced by social structures and co-evolves with relevant actors and institutions (e.g. Geels, 2002; Goldthau, 2014; Loorbach et al., 2010; Smith et al., 2005). While we acknowledge this perspective, we focus here on the key techno-economic dimensions of the electricity infrastructure. We argue that a simple dichotomy between decentralised and centralised infrastructure cannot capture the full range of concepts that pertain to electricity infrastructure development. Electricity infrastructure could be organised in a completely centralised or decentralised manner. More likely, however, is a simultaneous combination of centralised and decentralised designs. Furthermore, a single solution can incorporate centralised as well as decentralised characteristics; for example, centralised and decentralised power generation technologies can co-exist within an electric power system. We analyse the following infrastructure dimensions where centralisation or decentralisation can take place: (1) infrastructure location (connectivity and proximity of generation facilities), and (2) infrastructure operation (flexibility and controllability, including reliance on market mechanisms). The social and political

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http://dx.doi.org/10.1016/j.jup.2016.03.005
0957-1787/

dimensions of electricity systems that are closely related to the question of (de)centralisation, namely issues of system governance and democratic control, are touched upon briefly in the second section but are not the focus of this contribution.

We aim to develop a typology that clearly delineates key techno-economic dimensions of electricity infrastructure and describes potential (de)centralised infrastructure designs for the different dimensions. To demonstrate the typology, we apply it to two related smart-grid[1] demonstration projects and their respective techno-economic vision as well as a vision of a "Super-SmartGrid" for a future electricity infrastructure.

While German actors within the electricity system usually refer to the term 'decentralised energy system' when discussing transformation, the terms 'distributed', 'on-site', 'embedded' or 'dispersed' can also be found in the international literature (Ackermann et al., 2001; Pepermans et al., 2005; Alanne and Saari, 2006). In this contribution, we use the term 'decentralisation'.

The article is structured as follows. The following section presents incumbent as well as new actors in the electricity system and their positions on, and visions for, the layout of electricity infrastructure, which allows an understanding of the current context of the (de)centralisation discussion. In section 3, we examine various dimensions of the infrastructure, comparing decentralised with centralised design, highlighting interconnections between the dimensions and providing the structure of the typology. We use the developments in Germany as an example and consider how international developments influence the national level. On this basis, in section 4, we apply the (de)centralisation typology by considering two competing visions for the future of the electricity infrastructure. We finish with some concluding remarks on (de)centralisation and an outlook.

2. Competing visions of the future German electricity system

Incumbents on the one hand, and new actors and coalitions[2] on the other, pursue different agendas and have diverging if not competing visions for the future electricity system. The question of the degree of (de)centralisation arose in the wake of energy price increases and environmental concerns in the late 1970s and early 1980s (e.g. Lovins (1977) in the USA and Krause et al. (1980) in Germany). As explained in the literature on system transformation and its governance, such visions play an important role in the transformation process. The relevant literature provides insight into the workings of large socio-technical systems and possible transition pathways (Geels and Schot, 2007, 2010). Distinctive visions have already influenced the development of the electricity system for many decades, as Smith et al. (2005) describe for the introduction of nuclear power. A vision of the future can help to mobilise and coordinate actors and resources in the transformation process and provide a stable framework for target setting, but it also functions to support or criticise the status quo (Rotmans et al., 2001; Smith et al., 2005; Berkhout, 2006; Späth and Rohracher, 2010). The relevance of RES-E to visions for the German electricity system has dramatically increased since the 1970s, and especially since the current feed-in scheme was put in place in 2000. Moreover, there seems to be a consensus among most actors that RES-E will be the dominant source for electricity generation in the future. However, within this consensus there remain proponents of both the centralised and the decentralised vision and thus alternative transition pathways (cf. Verbong and Geels, 2012). The main arguments associated with these visions are presented here.

The vision of a mostly centralised system is based on large-scale power plants and balancing measures. Traditionally, nuclear and fossil fuels were essential to this system, but with the political decision to phase out nuclear energy in Germany by 2022 and the goal to decrease greenhouse gas emissions, larger shares of RES-E are expected for the future. Among this group of visionaries are scientists and consultancies that argue for a trans-European reinforcement of transmission grids (e.g. Helm, 2014; Czisch, 2011; PwC et al., 2010; PwC et al., 2011) as well as utilities that invest in large-scale power plants. They often ascribe the growing importance to renewables to sites in Europe and North Africa with the highest load factors and the lowest costs for large-scale RES-E deployment, including offshore wind parks and solar systems. Representative projects include Desertec (e.g. Pudlik et al., 2012) as an example of electricity generation, or the interconnector between England and the Netherlands, BritNed,[3] as an example of an advancing Europe-wide transmission grid integration (an example of a centralised vision is provided in section 4.2).

Over the past decades, starting with the environmental movement, other actors, supporting a decentralised vision for the electricity system, have entered the energy market (Mautz, 2007; Wissner, 2011). The introduction of feed-in tariffs (FiT) spurred this development as it allowed new actors with less financial resources to invest in generation. This is due to the design of FiTs, which guarantees a calculable remuneration for the electricity produced by smaller-scale and less capital-intensive RES-E power plants. Among these visionaries are private citizens,[4] politicians (e.g. Scheer, 2010), NGOs (Paulitzk, 2006), RES-E interest groups (BEE, 2011; Eurosolar, 2012), local initiatives or energy cooperatives (Hauber and Ruppert-Winkel, 2012) as well as companies from the ICT-sector, manufacturers of RES-E equipment, new electricity suppliers that were founded after electricity market liberalisation, farmers or project planners (Mautz, 2007; Wissner, 2011; Erlinghagen and Markard, 2012). While environmental concerns play an important role in the argumentation of these actors, they also stress the importance of regional energy structures as well as the relevance of renewables in self-sufficiency scenarios. They support their position with arguments linked to economic, social and political concerns (such as additional regional added value, a wider distribution of profits, reduction of market power, and a stronger democratic control of the electricity system; an example of a decentralised vision is provided in section 4.1). Many actors consider smart-grids as an essential technological aspect of this vision, flowing from early conceptions of decentralised electricity systems (Lovins, 1977; Krause et al., 1980) with a new emphasis on ICT-technologies and support from ICT interests.

The discourse concerning (de)centralisation of the electricity system is mainly driven by the actors and divergent positions described above. Our typology can inform the scientific and public debate because too often only certain dimensions or technologies of the system (such as generation or grids) are considered, while others (such as proximity or storage and demand-side management) are neglected.

[1] By smart grid, we mean the introduction of information and communication technology (ICT).

[2] For more details on actors and actor coalitions in the field of renewable energies in Germany, see Hirschl (2008) and Dagger (2009).

[3] For more information see: www.britned.com.

[4] Private citizens potentially influence the electricity sector as investors in RES-E equipment, as consumers and as voters of political parties that represent their interests.

Please cite this article in press as: Funcke, S., Bauknecht, D., Typology of centralised and decentralised visions for electricity infrastructure, Utilities Policy (2016), http://dx.doi.org/10.1016/j.jup.2016.03.005