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System- and actor-level challenges for diffusion of renewable electricity technologies: an international comparison

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ABSTRACT

It has become increasingly clear that a transition to low-carbon energy systems, including a widespread diffusion of renewable energy technologies (RETs), is necessary for the world to handle the challenges of climate change. Previous innovation system oriented research has identified barriers to development and early-stage diffusion of RETs, but more research is needed to understand what kind of institutional frameworks and governance tools are needed to achieve effective large-scale diffusion at a stage when technologies are commercially available and new demand-side actors become involved. The purpose of this paper is, therefore, to identify the main challenges faced by adopters of renewable electricity technologies under different institutional frameworks as well as their strategies for overcoming them. Results based on a qualitative multiple case study of 28 adopters in France and in Sweden show that adopters were faced with system-level challenges, such as market-structure obstacles and lack of institutional routines, as well as actor-level challenges, such as lack of resources or behavioral characteristics. The study also highlights the difference between blocking and restraining challenges and proposes that barriers are better thought of as challenges that can be overcome. It shows the importance for policy makers to consider not only system-level diffusion challenges, but also to understand actor-level contexts, including the behaviors of adopters who contribute to the transition. A further understanding how new entrants have managed to overcome existing challenges may provide new policy tools to facilitate the adoption for new adopters, for instance by encouraging the use of networks or by supplying specific information to potential adopters who lack it.

1. Introduction

It has become increasingly clear that a transition to low-carbon energy systems is necessary for the world to handle the challenges of climate change (IPCC, 2014) and it is now widely acknowledged that a widespread diffusion of renewable energy technologies (RETs) is a key to achieving this transition. However, so far only a small share of the world's energy supply comes from renewable sources.

This has stimulated quite a lot of research on innovation processes related to renewables, which has identified barriers to the development and early diffusion of technologies such as wind turbines, solar cells, hydrogen fuel cells and biomass digestion (cf., e.g., Agterbosch et al., 2007; Alam Hossain Mondal et al., 2010; Foxon et al., 2005; Jacobsson and Karltorp, 2013; Johnson and Jacobsson, 2001; Meijer et al., 2007; Negro et al., 2007; Suurs et al., 2009; Taylor, 2008; van Alphen et al., 2007; Viardot, 2013). Many of these studies show that there is interdependency between early-stage diffusion and the formation of well-functioning socio-technical systems around new technologies and, in consequence, that early technology diffusion can be blocked by weaknesses in these systems (cf. also Bergek et al., 2010; Klein Woolthuis et al., 2005; Negro et al., 2012).

However, so far our understanding of RET diffusion processes and their challenges remains limited. There are three main reasons for this. First, most of the innovation systems research has focused on understanding the formative phase of development of new energy technologies, rather than the widespread diffusion now necessary. Second, although it has provided important insights into the system-level barriers and opportunities for development and early diffusion, it has not explicitly taken into account demand-side actors (e.g. adopters of the technology) and their responses to institutional drivers and pressures. In theory, diffusion occurs

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through a gradual conquering of new market segments (Moore, 1998) and recent empirical research has shown that a broader group of demand-side actors, many without any previous experience of energy production, are now becoming involved in renewable electricity production (Bergek et al., 2013). This raises interesting questions about how effective diffusion can be achieved in an increasingly heterogeneous and inexperienced market. Third, previous research has tended to focus on barriers that prevent development and diffusion from taking place rather than on the conditions under which these barriers can be overcome by actors in the system.

Against this background, we would argue that more research is needed to understand what kind of institutional frameworks and governance tools are needed to achieve effective large-scale diffusion at a stage when technologies are more or less commercially available and new, entrepreneurial and resourceful adopters become involved and implement investment decisions in spite of any barriers in place. In line with this, the purpose of this paper is to identify the main challenges faced by adopters of renewable energy technology under different institutional frameworks (Sweden and France) as well as their strategies for overcoming them. Thereby, we can identify both factors slowing down the transition towards a low-fossil energy system and the means – energy policies and actor-level strategies – by which they can be overcome.

The outline of the paper is as follows. In Section 2, we review previous approaches to technology diffusion and provide a framework considering both system- and actor-level challenges. In Section 3, we explain the methodology used to gather the empirical data. In Section 4, we present and analyze the results of the 28 cases of adopters of renewable energy technology in France and in Sweden. In Section 5, we present our key conclusions and discuss some of the policy implications of these results.

2. Analytical framework

2.1. Approaches to technology diffusion

Three main strands of literature deal with technology diffusion and have all been used (and combined) in studies of energy transitions (see Table 1).

Diffusion modeling approaches try to describe and to some extent explain overall diffusion patterns (rates and total levels of adoption). Explanations primarily include endogenous mechanisms, such as competition, information exchange, learning effects and other increasing returns to adoption, but also to some extent exogenous factors, such as government policy and changes in energy prices (Montalvo and Kemp, 2008; Nill, 2008).[1] With regard to RET, a number of studies analyze learning curves and discuss how cost reduction has come about and the role of policy in this (Rao and Kishore, 2010). Explanations are, thus, sought at an aggregated level of analysis and there is hardly any room for individual actors to play a role in diffusion processes. Many diffusion models even fail to take into account the existence of heterogeneous actors (Nill, 2008).

Socio-technical systems approaches include, for example, the technological innovation systems (TIS) and multi-level perspective (MLP) frameworks, which both are interested in describing the underlying processes of innovation and diffusion at a system level and how these are influenced by institutional contexts of various kinds. As mentioned above, they tend to focus on the build-up and functioning of new socio-technical systems, emphasizing the close interaction between innovation and diffusion through early-stage learning by doing and using in early niche markets (cf., e.g., Bergek, 2012; Geels and Raven, 2006; Jacobsson and Johnson, 2000; Kemp et al., 1998). They have, however, not put much attention to the details of how diffusion processes unfold as new technologies leave the “protected spaces” of their early niche markets and, therefore, do not have much to say about the characteristics of later-stage markets. In part, this might be because they study diffusion against a backdrop of inertia, path-dependency and lock-in to incumbent technologies, actors and institutional structures, which often create barriers for widespread diffusion and prevent new technologies from breaking into the current regime (Markard and Truffer, 2008).

Innovation adoption approaches try to explain why, when and where adoption might occur (Montalvo and Kemp, 2008), emphasizing the importance of individual decision-making for technology diffusion. In particular, they argue that decisions to adopt, and the timing of such decisions, depend on (a) prior conditions related to potential adopters and the social systems they belong to (e.g. previous experiences and social norms), (b) characteristics of the decision-making unit, (c) perceived characteristics of the innovation and (d) communication patterns and channels (MacVaugh and Schiavone, 2010; Rogers, 2003; Venkatesh et al., 2003). With the primary exception of influences from institutional factors closely related to the potential adopters or their social networks, the innovation adoption literature seems to have a limited interest in understanding how adoption and implementation decisions are influenced by system-level factors and processes. One reason for this is, perhaps, that most of the empirical studies concern the diffusion of consumer products rather than capital goods. The latter are incorporated in proprietary business activities, which means that capital goods adopters become much more involved with the socio-technical system around the innovation than consumers who adopt a technology for their own, personal use.

While the approaches have been used to explain the early development and diffusion of innovations, neither approach captures all important aspects of later-stage diffusion. Diffusion modeling and socio-technical system approaches provide a good understanding of system-level processes and mechanisms influencing overall diffusion rates and levels, whereas innovation adoption provide insights into the impact of the characteristics of individual decision-makers within these systems. Diffusion modeling and innovation adoption approaches provide frameworks for understanding diffusion over time, which the socio-technical systems approaches generally lack. Diffusion modeling approaches explain the mechanisms that can create self-sustained diffusion, whereas socio-technical systems and innovation adoption approaches emphasize the institutional and actor-level barriers that could prevent such self-reinforcing mechanisms from emerging.

Therefore, in previous literature different approaches are often combined in order to better understand the behavior of system actors, the dynamics of innovation systems and their joint consequences for the diffusion of innovations. For instance, some authors have combined socio-technical approaches and innovation adoptions approaches in order to explore the conflict between system support and individual support of RE projects (Mallett, 2007; Wüstenhagen et al., 2007) and to explore how individual choices lead to the adoption of green electricity consumption (Ozaki, 2011). Others have combined innovation adoption approaches and diffusion modeling approaches in order to understand the contradiction between the high potential benefits of RET for adopters and the low diffusion of these technologies on a system level (Montalvo and Kemp, 2008). This is feasible since they share the agenda to explain why some innovations diffuse and others do not by

[1] For an overview of modeling approaches, see Meade and Islam (2006).