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The deployment of new energy technologies and the need for local learning

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ABSTRACT

The objective of this paper is to identify local aspects of technological learning in the deployment of solar photovoltaic (PV), a globally important form of distributed energy technology. We review literature in the economics of innovation and economic geography to identify the need for local learning when adopting new technologies and seek evidence on the local aspects of learning processes in the deployment of new (energy) technologies. The analysis focuses on the empirical evidence of learning processes in PV deployment. Our findings show that learning for PV deployment exhibits characteristics of local learning identified in the innovation literature (tacit knowledge, shared narratives, user relations and learning in interorganizational networks). In addition, we show that competencies in the deployment of PV rely on learning processes that are closely connected to the historically and geographically distinctive characteristics of the built environment. We also find evidence of the significance of proximity in (local) learning, as well as examples of knowledge being codified over time into national and global knowledge flows. We conclude with policy implications that acknowledge the importance of local learning for deployment.

1. Introduction

The transition towards a low carbon society is a major challenge that will require advances in innovation research and our understanding of technological change and innovation policy. More specifically, the transformation of the energy system will require a good understanding of the nature of technological change related to renewable energy technologies, including both theoretical conceptualizations and empirical evidence. A special case in point is the process of *deployment* of renewable energy technologies, i.e., the measures needed to get a technology into use and make it work in local contexts. This can involve symbolic work of domestication and societal embedding of new technologies (Sørensen 2013), but also very practical work of technology selection, design, acquisition, commissioning, installation and use, as well as the requisite administrative procedures (such as land use planning and permitting). So far, the innovation literature has had limited focus on the deployment of new energy technologies and such processes have rarely been explicitly defined or examined in the literature (e.g. Mignon and Bergek, 2016).

This research gap in the innovation literature on deployment of renewable energy technologies has opened up for research on learning (i.e., the development of technological capabilities) related to deployment of technologies such as wind turbines and solar photovoltaics (PV) (Langniß and Neij, 2004; Shum and Watanabe, 2007, 2008, 2009; Dewald and Truffer, 2012; Strupeit and Neij, 2016; Strupeit, 2016). These studies have highlighted the localized character of deployment and learning processes, thus opening the question: to what extent does deployment of different renewable energy technologies rely on *specifically local* learning and policy support.

In this paper we define *local* as a concept referring to a geographical and administrative area that is smaller than a nation state (i.e., a region, municipality or city), while acknowledging that the concept of local also suggests particular institutional, cultural and social commonalities and connections that may or may not coincide with geographical location (Maskell and Malmberg, 1999). Several researchers have highlighted the role of local governments in climate innovation (Hodson and Marvin, 2010; Bulkeley and Castán Broto, 2013) and particularly in the development of capabilities for renewable energy deployment (McCauley and Stephens, 2012; Mattes et al., 2014). Nevertheless, the deployment processes of new energy technologies, and their specifically local nature, remain largely underexplored and poorly conceptualized in the economics of innovation literature.

The intention of this paper is to provide support for improvement in innovation and energy policy. Our objective is to advance knowledge on technological change and the local deployment of new energy technologies, with a special focus on the learning aspects of deployment. We seek evidence of the extent to which various learning processes in the deployment of new (energy) technologies are local. We argue that the

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evidence and conceptualization of who learns in the deployment of new technologies, what is learned, and how space matters for this type of learning is still patchy. Mapping this territory from a systematic conceptual basis of local learning concepts is important for the identification of policy implications for different spatial levels.

The analysis of the local aspects of learning for technology deployment builds on two integrative reviews. First, we review literature in the economics of innovation (Nelson and Winter, 1977; Anon, 1988, 1992) and economic geography (Asheim, 1996; Maskell and Malmberg, 1999) on spatial aspects of technological learning. Second, we apply the conceptualizations found in this literature to empirical evidence of learning processes in PV deployment (see Annex 1 for detailed review methods). Based on these reviews, we aim to offer a more systematic understanding of the following questions: What type of learning processes related to the deployment of new energy technologies can be identified? To what extent are they local? How can these learning processes be supported?

We have chosen to analyse the deployment of PVs since it is a technology of major interest in the energy policy discourse on renewable energy technologies and most likely to rely on local learning for its deployment (Shum and Watanabe, 2008). PV modules are deployed and rendered into functioning energy production systems locally, whereas the development and production of PV modules is not a local activity. This may imply that local learning has a special role in the deployment of this technology, also given the emerging evidence on the geographically uneven adoption of PVs within countries (Müller and Rode, 2013; Graziano and Gillingham, 2015; Schaffer and Brun, 2015; Balta-Ozkan et al., 2015; Rode and Weber, 2016). Moreover, the deployment of PV modules relates to the downstream segment of the PV value chain, a segment that is likely to be at least in part localized and different from the upstream manufacturing industry, which deals with the development and production of new energy technologies.

Our paper is outlined as follows: Section 2 presents a review of the technological learning literature and its main conceptualizations concerning what is learned, who learns and how space influences technological learning. Section 3 presents the results of our integrative review of the literature concerning PV deployment, and compares this with the technological learning literatures. Section 4 discusses our findings and their limitations, and Section 5 presents conclusions and implications for policy and further research.

2. Conceptualization of local learning for technological change

The conceptual review on local learning for the introduction of new technologies presented in this section builds on literature in economics of innovation (e.g. Nelson and Winter, 1977; Lundvall 1988, 1992; Lundvall and Johnson 1994) and economic geography (e.g. Asheim, 1996; Maskell and Malmberg, 1999; Malmberg and Maskell, 2002). The point of departure is the learning economy (Lundvall and Johnsson, 1994), and our focus is on the local (sub-national) level of innovation rather than the national systems of innovation (Freeman, 1992). The review identifies concepts related to the introduction of new technologies and local learning processes. Although the paper has a focus on the deployment of new energy technologies, this review is broader and captures (local) learning processes related to technological change in development, manufacturing, and deployment under the following headings: (1) *what* is learned locally, (2) *who* learns and how and (3) *how* does spatial proximity support learning.

2.1. What is learned locally?

Knowledge is partly contained within a geographic (local) space due to the tacit nature of knowledge. Unlike mere information, knowledge requires social interaction, observation and personal communication for its transmission (Audretsch and Feldman 2004). Tacit knowledge refers to knowledge and embodied skill that is difficult to articulate, let alone codify (Polanyi, 1983; Polanyi, 1996/1997, p 136; Maskell and Malmberg, 1999). Tacit knowledge is sticky and thus may not travel easily beyond the context in which it was generated (Gertler, 2003). Because of this it is difficult to share, and it usually only moves with a small group of people sharing common traits or practices. Over time, pieces of such tacit knowledge become codified: in the case of technological learning, scientific and technological knowledge represents such codified knowledge. While formal, codified knowledge often is created by scientific and technological R & D, knowledge related to processes of doing certain tasks, using certain technologies and interaction among actors often remains tacit and highly localized, drawing on experience rather than codified and mobile knowledge (Lundvall and Johnson 1994; Jensen et al., 2007).

While the modern learning economy exhibits a strong tendency to codify knowledge, Maskell and Malmberg (1999) argue that not all pieces of knowledge are equally codifiable. Moreover, they argue that some tacit knowledge is needed in order to use codified knowledge, since codified knowledge does not carry with it the quality judgments and embodied routines required to use knowledge and build up consistent capabilities to continue using and accumulating it. A build-up of internal competencies is necessary for capturing external (codified) knowledge, appreciating its value and making use of it (Dosi, 1988).

Even formal professional knowledge involves a tacit component: Dosi and Nelson (2013) argue that industries at a given time exhibit “shared general design concepts” and “problem-solving heuristics” which include normative aspects like criteria for assessing performance, as well as characteristic ways of solving problems and directions in which solutions are sought. Hence, professional engineering knowledge, while much of it is distributed in codified form, also includes an element of tacit appreciation, orientation and propensity to use certain types of knowledge for certain types of problems.

The importance of codified and tacit knowledge varies by type of innovation. Asheim et al. (2007) distinguish between two different knowledge bases: analytical and synthetic. Industries (actors) building on an analytical knowledge base draw on scientific knowledge (genetics, biotechnology, IT) and hence, links to universities are important. Knowledge application is in the form of new products, processes and radical innovations. Synthetic knowledge is more relevant for the deployment of technologies, where the innovation takes place mainly in response to the need to solve specific problems arising in the interaction with clients and suppliers. Compared to an analytical knowledge base, learning concerns know-how, craft and practical skill and is often oriented towards the efficiency and reliability of new solutions, or the practical utility and usability of products meeting the needs of the clients (i.e, issues that are particularly important in the deployment of new technologies). According to Asheim et al. (2007), localized learning is more important for industries (actors) drawing on a synthetic knowledge base, although an analytical knowledge base can be drawn from a regional supportive infrastructure (e.g. local universities). Jensen et al. (2007) argue that the most successful firms combine both synthetic and analytical knowledge in their innovation processes.

A final point about the content of learning is its downside. Since learning and accumulation of tacit knowledge occurs continually, firms develop routines that are highly durable and path dependent and limit their capacity to respond to changes in the external environment (“competency trap”, see Levitt and March, 1988). Under changing conditions (e.g. rapid changes in factor costs) “unlearning” of existing routines and commitments may be necessary.

2.2. Who learns and how?

In the literature, learning has been considered on the level of individuals, organizations, collectives and – with some qualifications –