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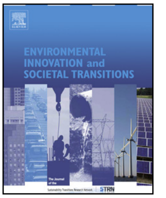

# An emerging innovation system for deployment of building-sited solar photovoltaics in Sweden

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The installed capacity for solar photovoltaic (PV) electricity production in Sweden is small but rapidly growing. In this paper, the emerging innovation system for the deployment of building-sited PV systems in Sweden is analysed in order to identify and assess drivers and barriers to diffusion, using a technological innovation systems (TIS) approach. As the market for PV systems in Sweden has grown, an increasing number and variety of actors have become engaged in PV deployment, and networks have been formed. The PV market has been utterly dependent on a government investment subsidy scheme, which has, however, effectively set a cap on the size of the market, leading to fluctuations in demand and difficulties for PV installation firms. The case study illustrates how the technological innovation systems (TIS) approach can be used in a deployment context to reveal system weaknesses.



## 1. Introduction

Photovoltaic (PV) solar cells are a renewable energy technology with an enormous potential to offset fossil fuel based electricity generation. In parallel to vast cost reductions, with prices of PV solar cells decreasing by more than 95% since 1980 (Carr, 2012), the installed global capacity for PV electricity generation has increased at an exponential rate, exceeding 150 $GW_p$ by mid-2014 (Barker,

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2014). Diffusion of PV worldwide has been utterly dependent on public financial support schemes stimulating demand for PV technology, thus creating early markets and learning opportunities for the PV industry, leading to reduced costs and thus, in turn, to more installed capacity. These subsidies have thus effectively stimulated the development of a global PV innovation system. In Sweden, however, installed PV capacity is smaller than in several comparable countries. Why is it so?

Although PV electricity is currently reaching grid parity (i.e. becoming as cheap as electricity bought from the grid) in an increasing number of regions, this does not necessarily lead to immediate commercial competitiveness, as high upfront costs and presumed hassle might deter potential users (Yang, 2010), a maladapted institutional set-up might hamper technology diffusion in various ways (e.g. Unruh, 2000), as may a lack of knowledge among key actors. While neoclassical economic analysis may be useful to understand incentives for investors and suppliers in a static socio-political context, a broader perspective is needed to tackle issues such as institutional change and learning processes. Karteris and Papadopoulos (2012) have shown that PV diffusion in a range of European countries follows patterns that cannot be explained by economic incentives alone.

Although the annual solar influx in Sweden is comparable to that in Germany, which is the world leader in terms of installed total PV capacity (IEA, 2013), the installed capacity in Sweden is very small; by the end of 2013, annual PV electricity generation was approximately 40 GWh, corresponding to a mere 0.03% of the total national electricity consumption (Lindahl, 2014). Nevertheless, the potential for building-sited PV considering Sweden's existing building stock has been estimated to 10–40 TWh/year (Kjellsson, 2000), which corresponds to about 7–30% of the country's current electricity production. For the levelized cost of PV electricity in Sweden to reach below grid parity, subsidisation is in most cases still needed (Stridh et al., 2013). About half of the Swedish power use is covered by nuclear power, but several nuclear power plants are approaching the end of their lifetime and there are strong political forces to substitute them with renewables once they are taken out of production. Wind power, which is highly feasible and increasingly common in Sweden, is neatly complemented by PV as these intermittent power sources rarely reach peak production simultaneously. The Swedish power grid, which reaches practically all households, is robust enough not to impose a bottleneck to widespread distributed PV diffusion (Widén, 2010).

This study aims to explain the slow diffusion of PV in Sweden using the technological innovation systems (TIS) framework. Since the Swedish market is small and PV value chains are global, the innovation system in Sweden is only partial. Feedback loops between use and technological learning and industrial production, which are normally at focus in TIS analyses, are missing. Yet this article will show that TIS is a helpful tool for analysing partial innovation systems, in this particular case that of the deployment (i.e. the processes in which the technology is put into use) of grid-connected building-sited PV systems in Sweden. This process includes e.g. installation and system integration, which are crucial for the diffusion (cf. Rogers, 1962) of the technology (considered here as an outcome of the deployment process). The analysis shows that, even though relevant actors and networks have proliferated over recent years, there are system weaknesses that require policy reform.

The paper is structured as follows. In Section 2, the theoretical framework is presented and discussed regarding the focus on technology deployment, and other methodological matters are accounted for. In Section 3, the structure of the Swedish PV innovation system is analysed and the functionality of the system is assessed; discussion is also carried out throughout this section. In Section 4, the main conclusions are presented and some challenges for policy are identified.

## 2. Research approach

### *2.1. Theoretical framework: technological innovation systems and technology deployment*

In this paper, a technological innovation system (TIS) approach (see e.g. Bergek et al., 2008a; Hekkert et al., 2007a) is adopted. This is one of several innovation system theories that have been developed since the 1980s to explain the nature and pace of technological change (see e.g. Carlsson and Stankiewicz, 1991; Edquist, 1997; Freeman, 1988; Lundvall, 1988). These theories describe the development and diffusion of technologies in general in a certain socio-political context (e.g. a nation), taking into account a broad set of societal factors driving and directing innovation. The TIS approach