Energy Policy 80 (2015) 153–164

Identifying barriers in the diffusion of renewable energy sources

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HIGHLIGHTS

- Firms in the Greek wind and solar power sectors assess RES barriers.
- Lack of financial resources is the most important RES barrier.
- Lack of a stable institutional framework negatively affects RES deployment.
- The support of the public sector is crucial to the diffusion of RES.
- Wind power faces strong legitimization barriers.

ARTICLE INFO

Article history:
Received 27 May 2014
Received in revised form
24 January 2015
Accepted 27 January 2015

Keywords:
Technological innovation systems
Resource mobilization barriers
RES Legitimization
Greece

ABSTRACT

Rapid diffusion of renewable energy sources (RES) in the electricity power sector is crucial if the EU wants to fulfill its 2050 CO_2 reduction commitments. For this reason, identifying and alleviating all barriers that hinder the development of RES is necessary to the successful deployment of these technologies. This paper discusses the main barriers in the diffusion of wind and photovoltaic (PV) solar power in the Greek electricity sector by drawing on the literature of technological innovation systems and system functions. Furthermore, we provide an explanation of the different diffusion rates between the two technologies. Inadequate financial resources, low grid capacity, delays in the issuance of building permits, opposition from local communities to the construction of wind farms and the lack of a stable institutional framework are among the most important barriers that inhibit the diffusion of the wind and PV solar power. The nature of the barriers identified in this study calls for policy intervention.

1. Introduction

Fossil fuels, which constitute the main energy source in the global energy mix, have been associated with increased carbon dioxide (CO_2) concentrations in the atmosphere. In 2011, global CO_2 emissions reached 31.3 $GtCO_2$, with the electricity and heat generation sector accounting for 42% of total CO_2 emissions (IEA, 2013). As widely acknowledged by the global community, CO_2 emissions have been responsible for the rise in global temperature and changes in the climate system. During the last decade, to reduce CO_2 emissions, governments have been focusing on designing efficient climate change policies such as emissions trading schemes or carbon taxes. However, although near-term, moderate emissions reduction goals can be achieved with the use of such economic price instruments, ambitious emissions reduction targets in the future will be very hard, if not impossible, to achieve without the pervasive diffusion of low-carbon technologies (Sandén and Azar, 2005).

Diffusion of renewable energy sources (RES) in the electricity sector could provide the basis for achieving mass reductions in CO_2 emissions in the long-term. To reduce its overall CO_2 emissions, the EU has set a target of 20% final energy consumption based on RES (Directive 2009/28/EC). Furthermore, EU leaders have committed to a 80–95% reduction of CO_2 emissions at the 1990 level by 2050 which, as it has been estimated, will not be possible unless a 95–100% decarbonization of the electricity sector is achieved (EU, 2011). Building on the above, the need for technological, institutional and social transition of the electricity system towards the use of RES in electricity production is of utmost importance.

The aim of this paper is to identify blocking mechanisms (or barriers) that hinder the diffusion of wind and solar[1] power in the electricity production sector. The theoretical framework used in this study draws upon the literature on technological innovation systems (TIS) and systems functions, which suggest that successful

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[1] In this study we will focus on the diffusion of *onshore* wind power and *photovolataic* (PV) solar power.

http://dx.doi.org/10.1016/j.enpol.2015.01.039
0301-4215/

diffusion of a TIS is possible only when a dynamic alignment of actors, networks and institutions, related to the particular system, takes place. Along this process, several blocking mechanisms will obstruct the transition of a particular TIS from a *formative* phase to a *take-off* (or growth) phase (Jacobsson and Bergek, 2004) by negatively affecting specific system functions. Identifying these blocking mechanisms forms the basis for developing and implementing targeted policy regulation.

It this study, we will focus on the barriers identified by firms in the Greek wind and solar power sectors that have hindered the diffusion of the two technologies. Furthermore, we will explain the different diffusion rates for each technology. Finally, we will conclude our study by making relevant policy recommendations to address those barriers that inhibit the diffusion of wind and solar power.

As shown in Fig. 1, the diffusion of wind power has been very slow during the last twenty years, despite the fact that demonstration projects started in 1983 and the country possesses very good wind power potential (IEA, 1999). The Greek National Renewable Energy Action Plan (NREAP) sets a target of 7200 MW installed for 2020. However, the penetration of wind power in 2013 was 1864 MW, which means that to fulfill the NREAP targets an average of approximately 1000 MW would have to be installed every year. If we take into consideration the fact that the annual installation of wind power has been approximately 80 MW/year and that the rate of wind power diffusion has been decreasing in recent years, we can conclude that deployment of wind power in the Greek electricity sector has not been successful. On the other hand, the target for solar power, which was first introduced in 2006 in the Greek market, has already been reached and cumulative PV capacity in 2013 was 2585 MW. Moreover, the diffusion rate of this technology has been over 100% for the last four years.

Furthermore, the development of a robust renewable energy sector in Greece could also provide the basis for overcoming the recent economic crisis as it offers many macroeconomic benefits (HWEA, 2012). First, it would contribute to GDP growth and consequently to the reduction of the public deficit. It has been estimated that for the years 2011–2020, RES could offer an additional 8.6–11 billion euro of GDP (HWEA, 2012). Second, it would create employment opportunities, thereby helping to reduce the high unemployment rate of the country, while at the same time offering additional income to local societies. For example, 3% of total wind farm revenues before taxation go to local municipalities. Finally, it would offer benefits in the form of CO_2 reductions, which has been estimated to be approximately 1.5 billion euro (HWEA, 2012). Building on the above, we can conclude that facilitating the diffusion of RES is crucial to the recovery of the Greek economy. Consequently, identifying those barriers that hinder the diffusion of wind and solar power is essential if we want to develop and implement an effective energy policy that will alleviate those barriers and create a path for a robust and sustainable economy.

This paper is organized as follows. Section 2 introduces the research framework and the methodology that will be used in our study. Section 3 presents the results and discusses the main findings of our research. Section 4 provides the conclusions along with policy recommendations and also presents the limitations of our study and offers suggestions for future research.

2. Methods

2.1. Literature review

The aim of this study is to identify the barriers that hinder the diffusion of wind and solar power. The rationale behind our research has its roots in the theories of technological innovation systems (Edquist, 1997; Freeman, 1987), national innovation systems (Nelson, 1993; Lundvall, 1992) and socio-technical regimes (Smith et al., 2005; Geels, 2004). These theories analyze the development and diffusion of new technologies by examining the actors of a particular technological regime, the networks through which they interact and the institutions that set the framework under which technological transition takes place. Socio-technical regime theory also utilizes the notions of agency and power to explain the transformation of technological regimes as a result of "the exercise of political, economic and institutional power" from the part of different actors in the regime (Smith et al., 2005).

All of the above theories explain the success or failure of a TIS on the basis of its structural components which include different *actors*, such as firms, the government, financial institutions, scientists and NGOs, the *networks* through which they interact and the relevant *institutions* (norms, regulation and laws). Analyzing a TIS by its structural components can provide us with a very good basis to comprehend the conditions under which technological transition takes place. However, when it comes to identifying key problems in a TIS that require specific policy recommendations, focusing only on the structural components of a TIS might be misleading because it is difficult to assess whether particular components of a TIS are either "good" or "bad" for the development and diffusion of the new technology (Bergek et al., 2008).

Several authors have proposed the concept of system functions to study the development and diffusion of TIS (Hekkert and Negro, 2009; Bergek et al., 2008; Hekkert et al., 2007; Negro et al., 2007). According to the above authors, TISs can be analyzed using a set of specific functions: entrepreneurial activities/experimentation, knowledge development and diffusion, guidance of the search,

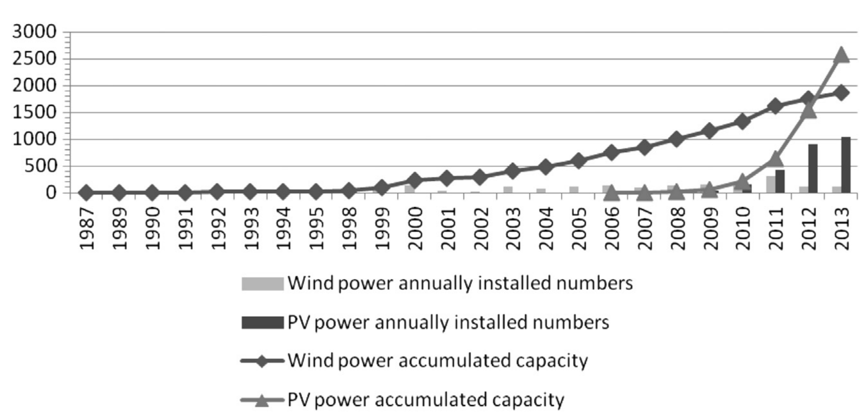

Fig. 1. Annually and cumulative installed (MW) wind and PV power in Greece.
Source: HWEA 2012; EurObserv'ER 2013.