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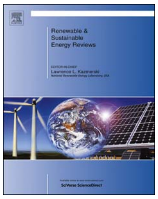

An overview of drivers and barriers to concentrated solar power in the European Union

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ABSTRACT

The aim of this article is to identify the most relevant drivers and barriers for the deployment of concentrated solar power (CSP) in the EU in a 2030 horizon, based on a thorough literature review and interviews with key stakeholders in the sector. The results of our interviews show that the higher "value" of CSP compared to other renewable energy sources (RES) is regarded as the most relevant driver, followed by the policy drivers (innovation and deployment support) and the significant cost reductions expected for the technology. The most relevant barrier is the high cost of the technology in comparison with conventional power plants and other renewable energy technologies, closely followed by uncertain and retroactive policies.

1. Introduction

In Solar Thermal Electricity (STE) technology, also called Concentrated Solar Power (CSP), mirrors concentrate solar energy onto a heat medium, which is then used to drive a conventional turbine. Designs either concentrate to a few hundred degrees (Parabolic/Fresnel designs) or to a maximum temperature for steam power cycles in power tower designs (around 600 degrees Celsius) [1]. There are four CSP plant variants, namely: Parabolic Trough (PT), Fresnel Reflector (FR), Solar Tower (ST) and Solar Dish (SD), which differ depending on the design, configuration of mirrors and receivers, heat transfer fluid used and whether or not heat storage is involved. The first three types are used mostly for power plants in centralised electricity generation, with the parabolic trough system being the most commercially mature technology.

As a still maturing technology, CSP is at an early deployment stage. It has experienced a substantial increase in deployment in the last years worldwide, although starting from a very low base. According to REN21 [2], total installed capacity in STE at the end of 2016 amounted to 4.81 GW, up from 600 MW at the end of 2009. Deployment has mostly taken place in two countries (Spain with 2300 MW and the U.S. with 1738 MW), although the technology has also been deployed elsewhere, including India, Morocco, South Africa, the United Arab Emirates, Algeria, Egypt, Australia , China and Thailand. However, only 110 MW were added in 2016 (100 MW in South Africa and 10 MW in China. The CSP market is dominated by the parabolic trough technology, both in terms of number of projects and total installed capacity (around 85% of capacity) [3].

The increase in deployment in the EU has been significant. From the 10 MW being installed in 2007, the current capacity deployed is 2311 MW [4]. The total installed CSP capacity to date in Spain represents 99.7% of the total installed capacity in the EU [4]. However, this is likely to change in the future, since only 50 MW are under construction or at an advanced stage of development and Italy seems to have taken over, with many projects under development.

The future deployment of CSP around the world looks bright according to different publications, which focus on the 2030 and 2050 timeframes. According to IRENA [5], CSP would reach between 52 GW (reference scenario) and 83 GW (Remap 2030 scenario). However, in its new Remap report [6], CSP deployment would only reach 44 GW in the reference scenario. The IEA [7] expected a much lower amount of CSP capacity being installed (110 GW in the 450 scenario). According to [8], STE could represent as much as 11% of electricity generation in 2050 under a high renewable energy scenario, with 954 GW of installed capacity. In its STE technology roadmap [9], the IEA updates those figures upwards, expecting 982 GW in 2050, with only 28 GW of those being deployed in the EU. These numbers are in line with the STE European industry association (ESTELA), which expects a worldwide diffusion of 1080 GW in 2050, 90 GW of which will be in Southern Europe [10].

According to the National Renewable Energy Action Plans (NREAPs), that each Member State had to submit to comply with the Renewable Energy Directive (Directive 28/2009/EC), installed capacity in the EU would reach 6765 MW by 2020 (4800 MW in Spain, 600 MW in Italy, 540 MW in France, 500 MW in Portugal, 250 MW in Greece

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and 75 MW in Cyprus). However, most of the countries that set objectives are way off target, and if no significant political changes are announced within the next two to three years, the sector will only reach 3130 MW in 2020 [4]. In fact, 3526 MW were expected for 2015 in the NREAPs, and only 2312 MW have materialized. Although CSP has some positive features (an almost infinite energy source without direct CO2 emissions and with heat that can be stored to continuously produce electricity, [11]), there are also barriers to the uptake of this technology.

The aim of this article is to identify the drivers and barriers for the deployment of CSP in the EU in a 2030 timeframe and to rank those drivers/barriers according to their relevance for different types of stakeholders. The relevance of each driver and barrier is worth analysing in order to propose appropriate policy portfolios which activate the drivers or mitigate the barriers for the effective and cost-efficient deployment of CSP.

The analytical framework of this paper is based on the systems of innovation approach. A combination of methodologies has been used. First, a desktop search of academic and technical documents in the literature on the drivers and barriers to CSP has been carried out. In a second stage, we have interviewed relevant stakeholders in order to gain further insights on those barriers and to rank their importance.

Whereas some technoeconomic analyses of CSP have been published (see, e.g. [9,12]), we are not aware of any comprehensive analysis on the future drivers and barriers to CSP technology. In fact, there are very few scholarly articles on CSP development. [11] examine the effects of introducing CSP transmitted through supergrids in five regions of the world, including Western Europe. The integrated assessment model WITCH is used to perform a numerical assessment of the economic and technological potential of CSP and its transmission over long distances. The analysis shows that an extensive use of CSP will generally become optimal after 2050. However, large scale deployment should occur after 2040. Viebahn et al. [13] provide an integrated dynamic assessment of technological development, cost development and lifecycle inventories of CSP in the EU and Africa until 2050. Interestingly, the authors consider 6 drivers influencing future technological development: security of supply, direct market support for renewable energies, preference for non-intermittent electricity generation, advanced side applications and side products, increasing demand for local added value and CSP being a conflict-neutral technology. However, a comprehensive analysis which takes into account the drivers and barriers, to CSP in the EU, with a prioritization of those drivers/barriers has not been carried out.

The rest of this article is structured as follows. The next section provides the analytical framework, including a discussion of the different drivers and barriers to CSP found in the literature. The method to identify the comparative relevance of those drivers/barriers is explained in Section 3. The results of the empirical study are discussed in Section 4. The article closes with some conclusions.

2. Analytical framework

2.1. Theoretical background: a systemic perspective on the drivers and barriers to CSP

Several contributions in the literature analyse the barriers to renewable energy technologies [14–19 among others]. In this paper, we follow innovation theory and, more specifically, a systems of innovation (SI) approach, since this provides a broader and richer picture of the innovation process in renewable energy technologies and, thus, offers a guiding heuristic on how support policies for electricity from renewable energy sources (RES-E) may influence this process.

The SI approach (see [20] for an overview) stresses that innovations are not developed and implemented in isolation but within a technological and socio-cultural context. It focuses on the importance and interdependencies of actors, networks, institutions, cumulative learning processes and spatial and technological characteristics [21]. It adopts a holistic perspective and considers phenomena such as path dependency, lock-in, interdependence, non-linearity and co-evolution [21,22]. This approach can inform us about how innovation occurs in relation to particular technologies, industrial sectors and specific national contexts, which system failures may be occurring, and how innovation may be influenced by incentives and policies [23]. An innovation system consists of three elements [24,26]: technology and related knowledge and skills, networks of actors and institutions. Networks of actors develop and implement new knowledge and technology, within their institutional context.[1] For an innovation system to be successful in developing and implementing technologies, these three building blocks need to be aligned.

This approach has already been applied to analyse renewable energy systems (see, among others [27–32]). These contributions stress that a shift to renewable energy technology systems is a complex process which involves changes in the aforementioned elements of an innovation system. They identify the multifaceted and systemic barriers to the development, commercialisation and diffusion of renewable energy technologies. These systemic barriers lead to lock-in through a path-dependent process driven by technological and institutional increasing returns to scale.

As it is well-known, the SI approach has been further developed along several directions (see [33]).[2] Among these, the technological systems of innovation (TIS) approach is particularly relevant in the context of this paper. A TIS is defined as a dynamic socio-technical system of agents that by interacting within a particular institutional infrastructure are involved in the development, diffusion, and use of a specific technology [34,35,20,36]. The TIS approach defines innovations in relation to the underlying technological base rather than in terms of sectoral considerations or geographical boundaries. The TIS approach has been made operative through the assessment in terms of system "functions" [36,37]. Different innovation systems can be assessed and compared in terms of the functions they fulfill in order to derive policy recommendations to support the development of a specific technology [43]. “Functions” are emergent properties of the interplay between actors and institutions [22]. The functions approach identifies those properties of a technological innovation system that are needed in order to successfully introduce sustainable energy technologies [37].[3]

The diffusion of renewable energy technologies into the incumbent energy system requires virtuous circles to be established between the different functions [37,44]. These may take place in a niche, which allows technologies to progress and create a supportive institutional environment around it. Niches can be created through public support. In addition to the demand and technology factors, this approach underlines the importance of several factors (characteristics of innovation, actors, networks and institutions, including regulations [44]). These factors influence each other, highlighting the importance of

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[1] These actors include: technology developers, technology end-users/owners, policy makers/government institutes, knowledge providers, entrepreneurs, service and maintenance providers, non-government organisations (NGOs), etc.

[2] These include national systems of innovation [38–40], regional innovation systems [41], sectoral systems of innovation and production [25] and technological innovation systems [34,42,43].

[3] [36] mention knowledge development and diffusion, guidance of the search, entrepreneurial experimentation, market formation, legitimation and resource mobilization. [31] distinguish between the creation of new knowledge, creation of positive external economies through exchange of information, demand articulation, recognition of a growth potential (connected to the legitimacy of a new technology), facilitation of market formation, supply of resources and arenas for coalition building and organisation of interests. For [43,44], these functions include entrepreneurial activities, knowledge development and diffusion, guidance of the search, market formation, resource mobilization and support for advocacy coalitions. [28] mention the creation and diffusion of new knowledge, the guidance of the direction of search among users and suppliers of technology, the supply of resources, the creation of positive external economies and the formation of markets.