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The geothermal potential in Spain

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ABSTRACT

With a potential geothermal generation of 610 GWt, Spain constitutes a promising EU-28 country for geothermal direct heating systems and binary cycle electricity production. Spain has a need to reduce energy consumption in buildings and in the secondary sector in order to comply with the Spanish Energy Plan 2011–2020, which establishes an objective of 50 MWe of electricity generation from geothermal energy and 66 MWt for direct heating use. Geothermal pumps are admissible in low and medium temperature heating schemes, but to achieve these energy savings targets, the most interesting way to generate energy is by using a CHP production from binary cycle plants. An analysis determining the energy consumption for Spanish dwellings shows that with a low-temperature design concept for district heating distribution, an organic Rankine cycle plant of 15 MWt with a geothermal temperature supply of 105 °C and a vector transportation fluid mass of 100 kg/s can cover 3% of the expected targets of electricity from geothermal sources and 15% of that expected for direct heating.

Contents

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1. Introduction

Total installed capacity from geothermal sources amounts to 60 GWth worldwide and roughly 20 GWth (1.85 GWe) in Europe, with Germany, Italy, and Sweden as the countries with the highest geothermal capacity installed in the EU-28 [1]. Even though the generation from geothermal energy has steadily grown in the EU-28 for the last 10 years, its total net production barely amounts a 0.2% [2], (it is expected that it will reach 0.3% by 2020) [3]. In spite of the fact that the geologic potential is very large in Europe (see Fig. 1a) and in the rest of the world (in fact, current electricity demand would be exceeded if all of it were used), the truth is that only a small portion of it can be profitable exploited [1]. It is expected that roughly 34 TWh might be potentially covered by 2030 (with geothermal energy resources) at a levelized cost of energy lower than 150 €/MWh [4]. Europe has a 37% of the world capacity, followed by the Americas and Asia with 32% and 27%, respectively [5]. Almost two-thirds of the geothermal installed capacity in the world corresponds to five countries, namely, USA, China, Sweden, Norway, and Germany [6]. Main geothermal regions in Europe are associated with both volcanic areas (such as Iceland and Italy) and medium enthalpy geothermal resources in sedimentary basins [7].

The European Union Energy Efficiency Plan 2012 [8] set a 20% overall reduction target for global PESs (by 2020) [9], thus emphasizing the necessity of implementing the means for reducing final energy consumption in buildings [10] (as this sector amounts to more than a third of the FEC) [11] taking into account thermal insulation capabilities and built-in lighting installation, and efficiency in hot water supply, air conditioning, and indoor climatic conditions.

The geothermal energy contribution in Spain in 2012 was barely 0.06% of the total installed capacity of power generation (108 GWe) [12,13]. Besides the pioneering European geothermal regions, the central region of Spain is being given much attention at a pan-European level and is considered to be a promising region for “new developments” [7]. As is well known, geothermal energy has some important advantages for energy supply due to 24/7 plant operations year round, but each geothermal location requires a prior analysis to determine its fluid and reservoir characteristics, chemical crystallization, and reinjection policy in order to avoid losses in the temperature profile or a reduction of the capacity factor (ratio of hours of plant operation with respect to the total yearly hours), which affect the financial and operational costs.

The geothermal resource is not easily attainable and is needed to perform the conversion into a type of directly usable energy, applying drilling procedures to extract from affordable underground reservoirs hot water, steam, or both fluids (defined as energy transportation vectors) placed at depths of 0.2–3.2 km in the Spanish territory; see Table 2. The transportation energy vector can be used in different technologies either for the use in pump heating or direct heating or to produce electricity in residential, agricultural, or industrial applications. In this paper, the possibilities to use these technologies in Spain and whether they can reach generation objectives will be examined. Geothermal fluids can be classified by considering temperatures, energy [14], or enthalpy [15–17] as the characteristic of their energy content. The advantage of the latter characterization lies in the fact that, by using this classification of enthalpies, one can immediately identify the transportation energy vector characteristics and the most appropriate energy application [18] (Table 1).

Following the European targets, the Spanish Administration has created the Renewable Energy Plan 2011–2020, with a geothermal energy goal of 50 MWe for electricity generation and 66 MWt for direct heating use (12.5 MWt intented to be used in direct-heat purposes and 53.5 MWt to be used with geothermal heat pumps) [19]. The first geothermal investigations and prospects in Spain started in 1948 by the Spanish Geologic and Mining Institute (IGME by its acronym in Spanish) at Lanzarote (Canary Islands); since then, new determinations have been performed along the Spanish territory. The current geothermal situation and distribution are shown respectively in Table 2 and (Fig. 1b), resulting in a low-medium enthalpy resources potential of 610 GWt [20,21]. As it is possible to see in Table 3, a total of 22 MWt is applied to the heating and cooling sectors (at a capacity factor of 50%) [22]. No additional installations have been performed from 2011, and, currently, there are no geothermal plants in Spain associated with DH networks nor generating electricity. Only in the Canary Islands may it be technically feasible to use EGS technology, which is considered to be the most challenging issue facing the geothermal energy sector – it can supply superheated steam as an energy transportation vector that can be transformed directly into electricity [1].

From the classical (still valid, 1973) Lindal diagram, which indicates geothermal applications for various temperatures, it is possible to infer that most HTGRs' end-use is electricity production [23,24]. In general, higher enthalpy resources commonly need a pressure flash separation process to obtain two fluid streams, namely, a steam line that drives one or more Rankine cycles and brings electric power generation [25] and a hot water line, or brine, that can be used in either a binary cycle plant (also allowing electric power generation) or in a direct-use application (it should be noted that 25 percent of the EU-28 population lives in areas suitable for geothermal district heating technology) [26]. The returning two fluid streams are recovered to maintain reservoir activity [27,28]. Another possibility is using binary power plants, which also enables the use of hot water as a transportation vector resource for electric power generation from medium enthalpy reservoirs.

Section 1 briefly discussed total installed capacity from geothermal sources across the world and in particular in Spain, where the Spanish administration's targets in terms of geothermal energy are shown; in Section 2, the method used to conduct the review here presented will be exposed; in Section 3, which is reserved for the theory background, flash and binary power plants, direct heating technology, the characterization of geothermal sources, and the average residential energy demand in Spain will be presented; subsequently, in Section 4, results for ORC plants in geothermal applications using district heating networks will be shown. Section 5 is reserved for discussion and conclusions, where the energetic consequences resulting from the implementation of geothermal resources in district heating systems are presented. Finally, an Appendices section has been included to provide extra information about low, medium, and high-temperature geothermal resources in Spain. Supplementary material on heat pumps,