Renewable Energy 66 (2014) 1–14

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

An estimation of the enhanced geothermal systems potential for the Iberian Peninsula

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A R T I C L E I N F O

Article history:
Received 23 July 2013
Accepted 25 November 2013
Available online 15 December 2013

Keywords:
Geothermal energy
EGS
EGS theoretical technical potential
Iberian Peninsula

A B S T R A C T

An estimation of the Enhanced Geothermal System's theoretical technical potential for the Iberian Peninsula is presented in this work. As a first step, the temperature at different depths (from 3500 m to 9500 m, in 1000 m steps) has been estimated from existing heat flow, temperature at 1000 m and temperature at 2000 m depth data. From the obtained temperature-at-depth data, an evaluation of the available heat stored for each 1 km thick layer between 3 and 10 km depth, under some limiting hypotheses, has been made. Results are presented as the net electrical power that could be installed, considering that the available thermal energy stored is extracted during a 30 year project life. The results are presented globally for the Iberian Peninsula and separately for Portugal (continental Portugal), Spain (continental Spain plus the Balearic Islands) and for each one of the administrative regions included in the study. Nearly 6% of the surface of the Iberian Peninsula, at a depth of 3500 m has a temperature higher than 150 °C. This surface increases to more than 50% at 5500 m depth, and more than 90% at 7500 m depth. The Enhanced Geothermal System's theoretical technical potential in the Iberian Peninsula, up to a 10 km depth (3 km–10 km) and for temperatures above 150 °C, expressed as potential installed electrical power, is as high as 700 GW_e, which is more than 5 times today's total electricity capacity installed in the Iberian Peninsula (renewable, conventional thermal and nuclear).

1. Introduction

Geothermal energy is the thermal energy stored in the Earth's crust. Geothermal resources comprise not only the scarce and highly localized hydrothermal resources, which have been used worldwide for both thermal and electric applications for decades, but also the widespread thermal energy stored in deeper layers of the Earth's crust. There are several well established technologies for electricity production from hydrothermal reservoirs. A detailed description of the surface and subsurface technologies can be found in the literature [1,2]. Geothermal power plants based on these technologies are running in at least 24 countries in the world. Today, installed power capacity exceeds 10,000 MW, and the annual energy produced is close to 70,000 GWh [3–5].

The so-called Enhanced Geothermal Systems (EGS) [6,7] will allow the exploitation of geothermal energy in locations other than hydrothermal reservoirs. In 2006, the Massachusetts Institute of Technology (MIT) published a report on the future of geothermal power. The main conclusion was that EGS could produce 100 GW_e in the U.S. alone by 2050, if a reasonable investment was guaranteed [8]. In the last few years, EGS technology has been tested in several experimental plants around the world [9–14] and the results obtained, even when some technological and geological related questions have not yet been completely solved, are quite promising [8,15]. In Europe, some of the main projects are that of Soultz in France [10], and those of Hortsberg [16] and Gross Schoenebeck [17] in Germany.

Geothermal power is a renewable energy source, with a minimum environmental impact [1,18]. Compared with other renewable sources, it has important advantages such as its no-time-dependant nature and its very high capacity factor (as high as 95%). These characteristics mean that it can be used as a base-load power source. The development of the EGS technology will increase the geothermal resource but, as a previous step, it is necessary to make estimations of the magnitude of the EGS potential on a regional scale.

2. Objectives

The aim of this work is to give an estimation of the EGS theoretical technical potential (as defined by Rybach [19–21] and Van

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http://dx.doi.org/10.1016/j.renene.2013.11.065

Table 1
Regions considered in the study, region NUTS code according to the nomenclature of territorial units for statistics of the European Union, surface in km^2 and as a percentage of the total, calculated mean value of the surface heat flow rate, percentage of the surface of each region with available data of the temperature at 2000 m depth and Natural Protection Areas factor.

Region	Region NUTS code	Surface	Surface	Mean surface heat flow	Surface with T_{2000} data	F_{NPA}
		km^2	%	mW m^{-2}	%	
Iberian Peninsula	IP	587,857	100.0	73.3	47.3	0.260
Spain (continental + ES53)	ES	498,598	84.8	73.3	49.0	0.269
Portugal (continental)	PT	89,259	15.2	72.9	38.0	0.210
Galicia	ES11	29,644	5.0	108.2	0.0	
Principado de Asturias	ES12	10,610	1.8	51.8	19.2	
Cantabria	ES13	5317	0.9	58.6	100.0	
País Vasco	ES21	7229	1.2	74.4	100.0	
Comunidad Foral de Navarra	ES22	10,385	1.8	71.4	100.0	
La Rioja	ES23	5042	0.9	68.4	100.0	
Aragón	ES24	47,730	8.1	72.4	100.0	
Comunidad de Madrid	ES30	8023	1.4	68.5	46.3	
Castilla y León	ES41	94,225	16.0	72.5	36.2	
Castilla-La Mancha	ES42	79,414	13.5	69.7	55.7	
Extremadura	ES43	41,679	7.1	80.5	0.0	
Cataluña	ES51	32,203	5.5	77.0	100.0	
Comunidad Valenciana	ES52	23,264	4.0	76.6	100.0	
Islas Baleares	ES53	4917	0.8	71.5	0.0	
Andalucía	ES61	87,608	14.9	66.0	20.5	
Región de Murcia	ES62	11,309	1.9	66.5	99.7	
Norte	PT11	21,350	3.6	91.9	0.6	
Algarve	PT15	5016	0.9	78.1	97.6	
Centro	PT16	28,299	4.8	65.9	29.9	
Lisboa	PT17	2918	0.5	75.4	95.0	
Alentejo	PT18	31,677	5.4	65.2	55.6	

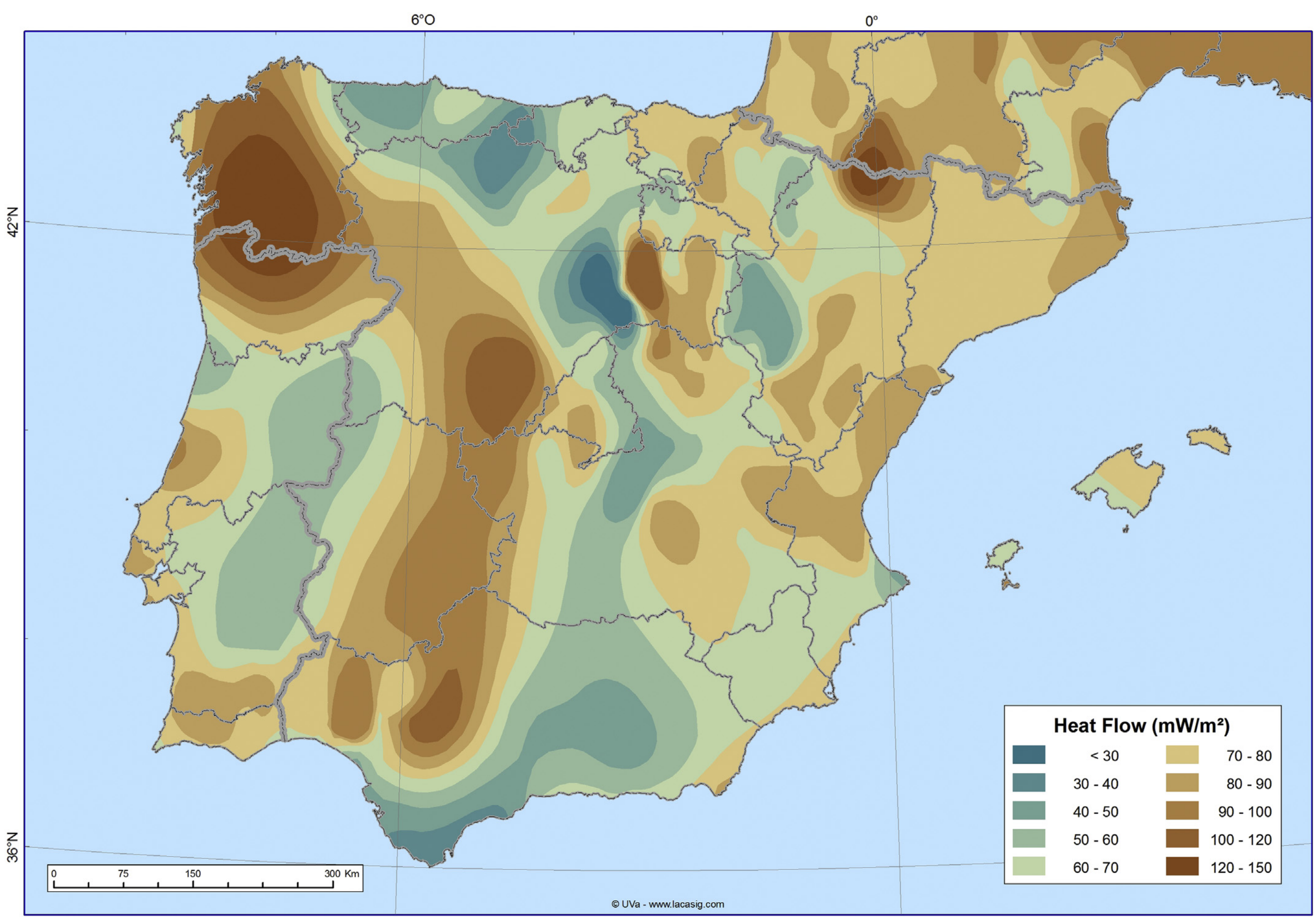

Fig. 1. Surface heat flow rate map of the Iberian Peninsula extracted from the Atlas of Geothermal Resources in Europe [26].