

Production, consumption and research on solar energy: The Spanish and German case



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ABSTRACT

An analysis of scientific publications on solar energy was conducted to determine whether public interest in the subject is mirrored by more intense research in the area. To this end, the research published by Spain and Germany, the two EU countries with the highest installed photovoltaic capacity, was analyzed based on Web of Science data. The results show that: solar output has risen substantially; solar research has a greater impact (measured in terms of citations) than publications on other renewables such as wind power; scientific production on solar energy is high in Germany and Spain, which together account for 51% of the total in the EU-27; the pattern of topics researched in the two countries is very similar; and their international collaboration is more intense than the world average and higher than in countries such as the USA, China or Japan. Collaboration between them is likewise intense. The main conclusion is the divergence in Germany and Spain between solar energy demand/output growth, being exponential, and the growth of research papers on the subject, which is linear.

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1. Introduction

Research, development and innovation in the field of renewable energy, is closely related to investment and national policies, especially in regard to obtaining sustainable resources [1]. In this respect, countries and institutions are the main actors of research on this type of energy production.

The countries in the European Union have a huge interest in the promotion of the use of renewable energy sources. By developing less dependence on fossil fuels from countries outside the EU the emission of CO₂ is reduced, which is an advantage from both energy, environmental and economic perspectives. This interest is specified in legislation with Directive 2009/28/EC [2] from the European Parliament on promotion of the use of energy from renewable energy sources which outlines a set of goals to be achieved by 2020.

Moreover, the OECD raises an awareness related to the importance of sustainable developments through various programs that enhance their study and promotion, especially in the field of sustainable growth and so-called “Green growth” [3,4].

Political decisions on renewable energy in the EU are becoming increasingly important, as evidenced by the increased generation and consumption of energy from alternative sources, with continued growth in recent years, although they are still far from reaching the goal set for the year 2020, where 20% of energy production should come from renewable energy sources (Fig. 1) [5]. The target of 20% is an overall target for the entire EU, and individual countries have their own targets.

An analysis of the evolution of this energy consumption by country (Table 1), indicates that primarily in Scandinavia and Eastern Europe the percentage of energy produced by alternative sources exceeds the overall 2020 target reaching well above the countries of the Central European region and the Mediterranean [5].

Among the renewable energy sources, the largest share of energy production capacity derives from wind and solar energies. As shown in Fig. 2, especially wind power demonstrates a remarkable

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growth in the EU since the 90s [6], while a similar boost of solar energy production initiates in the middle of the last decade (2005–2006).

Energy production from solar sources as such already started in the mid-90s. Germany and Spain are the two European countries that are making the greatest effort with respect to this type of energy (Fig. 3), which contributes to reducing emissions of significant amounts of CO₂ to the atmosphere, as well as creating so-called “green jobs”, largely related to the development, production and installation of photovoltaic systems.

When looking at the data on the installed photovoltaic capacity in the 27 EU countries at the end of 2009 Germany and Spain top the list, followed by Italy, the Czech Republic and Belgium (Fig. 3). The same top position applies in relation to the photovoltaic capacity per capita (Table 2), but with Italy at a lower ranking. Furthermore, the Eurostat data (Table 3) show that Spain and Germany have a much higher growth in production of solar energy than the EU overall. While the production in the EU has increased by a factor of 21 1995–2011, it has increased by factors of 52 and 58 in Spain and Germany, respectively [7].

From a bibliometric and scientometric perspective several studies have been conducted that analyze different papers have studied the literature on renewable energy in general and solar energy in particular. For example, Garg and Sharma [8] observed the great growth of publications on collectors and solar cells after the 1973 energy crisis. Tijssen [9], based on co-classification analysis shows the interdisciplinary structure and sources of renewable energy research in the Netherlands. Celik et al. [10] analyzed the different trends in renewable energy research in Turkey and showed the important role played by solar energy within them. Recent bibliometric research on India highlights the importance of solar energy in this country, and the significant weight of its scientific production on the global scene [11,12].

Dong et al. [13] analyzed the literature on solar energy and also observed an important growth of publications between 1991 and 2010 and concluded emphasizing the importance that research on solar cells will have in the 21st century. Romo-Fernández et al. [14] discuss research on renewable energy in different European countries. They show the leading role of European institutions in this field, with a large scientific production and a higher impact than the world average. In a later article [15] they focus their analysis on production of renewable energy research in Spain compared to a global context. They point to the increasing presence of publications authored by Spanish institutions in the area of renewable energy and in particular to the increase in solar energy research.

The overall aim of this paper is to determine whether the increase in the societal interest in solar energy is reflected in an

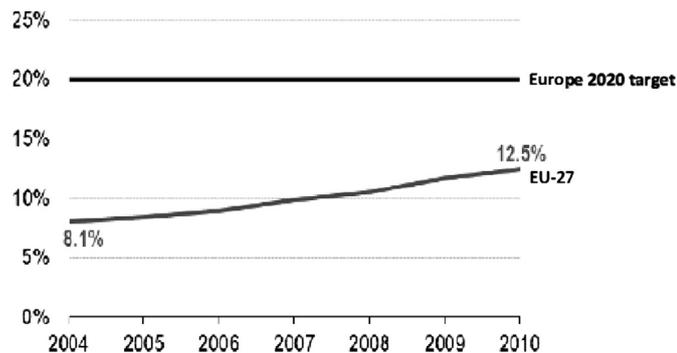


Fig. 1. Percentage of consumption from renewable energy sources (2004–2010).

Table 1
Percentage of consumption from renewable energy sources by country (2004–2010).

	2004	2005	2006	2007	2008	2009	2010	2020 target
EU-27	8.1	8.5	9.0	9.9	10.5	11.7	12.5	20
Belgium	1.9	2.3	2.6	2.9	3.3	4.5	5.1	13
Bulgaria	9.6	9.5	9.6	9.3	9.8	11.9	13.8	16
Czech Republic	6.1	6.1	6.5	7.4	7.6	8.5	9.2	13
Denmark	15.1	16.2	16.5	18.0	18.8	20.2	22.2	30
Germany	5.1	5.9	6.9	9.0	9.1	9.5	11.0	18
Estonia	18.4	17.5	16.1	17.1	18.9	23.0	24.3	25
Ireland	2.2	2.7	2.9	3.3	3.9	5.1	5.5	16
Greece	6.9	7.0	7.0	8.1	8.0	8.1	9.2	18
Spain	8.2	8.3	9.0	9.5	10.6	12.8	13.8	20
France	9.3	9.5	9.6	10.2	11.3	12.3	12.9	23
Italy	5.3	5.3	5.8	5.7	7.1	8.9	10.1	17
Cyprus	2.4	2.4	2.5	3.1	4.1	4.6	4.8	13
Latvia	32.8	32.3	31.1	29.6	29.8	34.3	32.6	40
Lithuania	17.1	16.9	16.9	16.6	17.9	20.0	19.7	23
Luxembourg	0.9	1.4	1.4	2.7	2.8	2.8	2.8	11
Hungary	4.4	4.5	5.1	5.9	6.6	8.1	8.7	13
Malta	0.1	0.1	0.2	0.2	0.2	0.2	0.4	10
Netherlands	1.9	2.3	2.7	3.1	3.4	4.1	3.8	14
Austria	22.9	25.0	26.6	28.9	29.2	31.0	30.1	34
Poland	7.0	7.0	7.0	7.0	7.9	8.9	9.4	15
Portugal	19.2	19.6	20.8	22.0	23.0	24.6	24.6	31
Romania	16.8	17.6	17.1	18.3	20.3	22.4	23.4	24
Slovenia	16.2	16.0	15.5	15.6	15.1	18.9	19.8	25
Slovakia	6.1	6.2	6.6	8.2	8.4	10.4	9.0	14
Finland	29.1	28.7	29.9	29.5	31.1	31.1	32.2	38
Sweden	38.7	40.6	42.7	44.2	45.2	48.1	47.9	49
United Kingdom	1.1	1.3	1.5	1.8	2.3	2.9	3.2	15
Norway	58.4	60.1	60.6	60.5	62.0	66.1	61.1	67.5
Croatia	15.2	14.1	13.8	12.4	12.2	13.2	14.6	20

increase of research on this type of energy, measured primarily by analyses of publications. To do this, we have analyzed the publications of the research institutions in Spain and Germany, as they are the two EU countries with the highest installed photovoltaic capacity. The analyses will establish the publication patterns in terms of temporal evolution, the main subjects, the publication sources, the most productive institutions as well as international scientific collaboration in the field of solar energy research.

The article is structured as follows. First, a methodological section describes the data collection, including the retrieval profiles, and the means of data analysis in the form of indicators used. This is followed by result sections that first provide findings on renewable energy as such, followed by findings on solar energy research, particular topics, central journals, major research institutions in Spain and Germany, and international collaboration patterns. The article ends with a discussion of perspectives and conclusions.

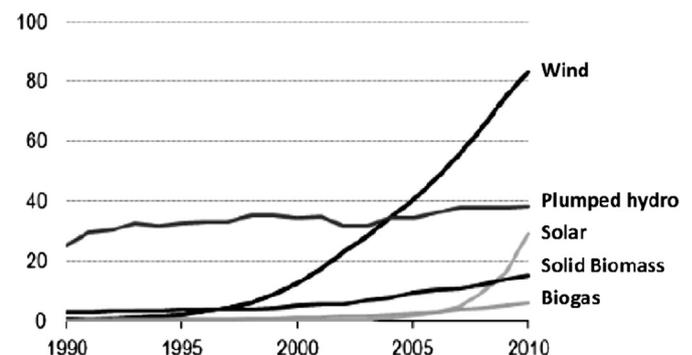


Fig. 2. Renewable energy production capacity (in gigawatts) by energy type in the EU (1990–2010).

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