



Renewable energy production in Spain: A review



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ABSTRACT

This paper reviews the production and consumption of traditional and renewable energy in Spain over the past two decades. It also presents an overview on the development of renewable energy, such as solar (photovoltaic and photothermal), wind, biomass, hydropower, marine and geothermal energies in Spain. A brief overview of the legislation regulating renewable energy in Spain is offered. It was shown that the installed renewable energy of 32,472 MW represented 11.6% of the country's primary energy consumption. Furthermore, the installed renewable energy average of electric power in Spain was 0.7 kW per capita and 59 kW/km². Wind energy continues to experience a good growth rate, and does not seem to be affected by regulations, which has made it the most sustainable renewable energy in Spain. Finally, an analysis of energy production and consumption, renewable and non-renewable energy by province is made. The data indicates that highly populated and industrialised provinces made more efficient use of their energy from an electrical consumption viewpoint. This uneven growth was not motivated solely by the existence or lack of renewable energy resources but by the autonomous community or province in their socio-economic context.

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1. Introduction

The growing need for energy in western societies and, above all, in developing ones, has posed a major challenge to the

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Table 1

National overall targets for the share of energy obtained from renewable sources, expressed in terms of the gross final consumption of energy in 2020.

Countries	Share of energy from renewable sources in gross final consumption of energy, 2005%	Target for share of energy from renewable sources in gross final consumption of energy, 2020%
Belgium	2.2	13
Bulgaria	9.4	16
Czech Republic	6.1	13
Denmark	17	30
Germany	5.8	18
Estonia	18	25
Ireland	3.1	16
Greece	6.9	18
Spain	8.7	20
France	10.3	23
Italy	5.2	17
Cyprus	2.9	13
Latvia	32.6	40
Lithuania	15	23
Luxembourg	0.9	11
Hungary	4.3	13
Malta	0	10
Netherlands	2.4	14
Austria	23.3	34
Poland	7.2	15
Portugal	20.5	31
Romania	17.8	24
Slovenia	16	25
Slovak Republic	6.7	14
Finland	28.5	38
Sweden	39.8	49
United Kingdom	1.3	15

establishment of new energy policies [1]. Traditional approaches have increased generation with increasing needs [2], but recent years have seen a greater emphasis on energy-saving strategies [3] and sustainability [4,5]. The industrial sector, which uses more energy than any other end-use sectors, currently consumes approximately 37% of the world's total delivered energy [6].

The success of the evolution of human civilisation has been linked to the orderly and sustainable growth of resources and energy utilisation [7]. Forecasts and trend studies have indicated that civilisation is now facing a major energy challenge, and it will not be easy to achieve the objectives set for the coming years, especially with the pressure of large growth in emerging countries such as India [8–10], China [11], and Brazil [12,13]. This pressure has stemmed from high levels of underdevelopment, especially in rural areas [14–16], and underdeveloped countries aspire to catch up to the developed countries and engage in the greater consumption of energy that this achievement implies [17]. It has become clear that the measures and policies needed to implement solutions on the global level should be developed using the factors mentioned above, including research [18], the contribution of renewable energy sources [19–21], and the utilisation of urban, agricultural [22,23], and industrial waste [24] as new sources of energy [25].

Nearly 40% of the European Union's final energy demand comes from domestic public and corporate consumption [26]. According to Europe's Energy Efficiency Plan, the biggest energy savings potential in the EU lies in the built environment [27]. The EU is one of the major drivers of efficiency measures [28], energy savings [29,30], and the development of renewable energies [31]. European governments have agreed to increase the share of renewable energy in final energy consumption to 20% by 2020 [32]. The EU's energy policies have been active since 1986 due to the

initiatives of the European Council. With Directive 2009/28/EC, the European Parliament and Council have laid the ground for a policy framework on renewable energy sources (RES) in the European Union until 2020 [33]. Programs, such as ALTENER, and reference documents, such as the White Papers [34,35] and Green Papers [36], have allowed for the advancement of sustainable energy growth policies that aid in the fight against global warming and climate change. The EU Green Paper on energy efficiency has called for action to decrease energy use and thus achieve increased competitiveness, fulfil environmental targets, and increase the security of the region's energy supply [36]. The promotion and stimulus of the renewable energy sector (RES) has been one of the clearest examples in this regard. Under the Kyoto protocol, the European Union (EU) has agreed to reduce greenhouse gas (GHG) emissions by 8% between 2008 and 2012 relative to 1990 levels. For example, tradable green certificate (TGCs) schemes have been developed and tested in several European countries to foster the market-driven penetration of renewable energies. These certificates guarantee that a specific volume of electricity is generated from renewable energy sources (RES) [37]. Table 1 shows the target renewable electricity production quotas in relation to the total production for the 2020 horizon [38]. The data show that the specified renewable energy production goals were achieved until 2020, but the majority of countries in the EU-27 have distanced themselves from their objectives since 2011. As a result, only Estonia, Austria and Sweden will be able to fulfil their national goals for 2020.

Spain is a clear example of a negative trend in the fulfilment of the 2020 renewable energy objectives. Recent reports have shown that the best-case scenario projection is within the range of 12.6–17.1%, far from the forecasted goal of 20%. The projection also represents a clear breach of the objectives in the National Action Plan for Renewable Energy [39], which gives a goal of 22.7%, and the plan drawn up by the Spanish government through the Plan for Renewable Energies (Spanish initials PER), which forecasts 20.8% over 2011–2020.

Energy dependence indicator shows the extent to which an economy relies upon imports in order to meet its energy needs; it is calculated as net imports (total imports minus total exports) divided by the sum of gross inland energy consumption [40]. Energy dependence may be negative in the case of net exporter countries while positive values over 100% indicate the accumulation of stocks during the reference year.

These failures have meant that Spain's energy dependence (see Fig. 1) will continue to be a key factor in the country's economic recovery and emergence from crisis [41]. Spain's energy dependence (76.44%) is well above the average for the EU-27 (53.84%). Only Denmark has a negative balance because wind power has been the main element of Danish renewable energy policy [42].

Spain's dependence has only increased in recent decades, although the impetus of the renewable energy sector has reversed this trend since 2007 (see Fig. 2). The Spanish government approved the Renewable Energy Plan in 2005, assuming a goal of 12.1% RES-E share by 2010 and an overall renewable share of 22.7%, or 37.5% when considering only the electricity sector [43].

Spain consumed 14.9 Mtoe of renewable energy in 2011, which represented 11.6% of the country's primary energy consumption. Biomass, wind and hydropower are the main sources of renewable energy. In terms of power generation, the gross renewable energy production amounted to 86,600 GW h, or 29.7% of the country's total. This distribution implies that renewables are the main source of electrical energy for the country, surpassing natural gas (28.9%) and nuclear power (19.7%). The distribution within the renewable energy sector by type has indicated an 84% contribution by wind and hydropower (49% and 35%, respectively), which is an

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