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Achieving Blue Growth through maritime spatial planning: Offshore wind energy optimization and biodiversity conservation in Spain

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ABSTRACT

Spain has a high potential for renewable energy production, being the world's third country by installed on-shore wind power. However, it has not yet fully developed its renewable energy production capacity, with no commercial offshore wind production to date, and remains highly dependent on fossil fuel imports. The country is also one of Europe's most biodiverse, on land and at sea. This study spatially assesses the country's offshore wind energy potential by incorporating the newly designated marine protected areas (MPAs) to the official Spanish strategic environmental assessment for the installation of offshore windfarms (SEA). It also identifies optimal areas for offshore windfarm development according to key physical variables such as wind speed, depth and substrate type. It finally assesses real commercial windfarm projects against current environmental constraints. The results show that nearly 50% of the whole area within 24 nm from the Spanish coast could be suitable for offshore windfarm development at the planning phase. However, only 0.7% of that area is optimal for wind energy production with current fixed turbine technology. Nevertheless, either area would allow Spain to meet its national targets of 750 MW of ocean power capacity installed by 2020 under adequate local wind conditions. Over 88% of all commercial windfarm project area is within the SEA's *Exclusion zone*, thus unfeasible under current circumstances. Technological breakthroughs like floating turbines may soon make the optimal windfarm area (OWA) less restrictive and reduce current environmental impacts of marine windfarms within a truly sustainable Blue Growth.

1. Introduction

A number of reasons have increased global interest in marine renewable energy development: fossil fuel exhaustion risk and price oscillation; high competition for and disagreement on land uses; exclusive or better energy production conditions in the marine environment (e.g., in terms of wave or wind energy, respectively); and a need to abate climate change [24]. Offshore wind energy is one of the most rapidly growing marine renewable sources. In Europe in 2015, there were 84 offshore wind farms (including those under construction), with a 108% increase in net installed, grid-connected capacity respective to 2014, most of it developed by Germany, the UK and the Netherlands in the North Sea [20].

The Directive 2009/28/CE, of the European Parliament and the Council, on the promotion of the use of energy from renewable sources, sets up minimal compulsory targets on the use of at least 20% of the final countries' gross energy consumption coming from renewable sources by the year 2020 [12]. The Directive is part of the European Union's Package on Energy and Climate Change [16], which was recently updated and stiffened for the 2020–2030 period [17]. Following the Directives' dictates, the Spanish Government passed the Law 2/2011 on Sustainable Economy, which established the target of attaining 20.8% of final gross energy consumption from renewable energy sources in the country by 2020. Achieving that target is especially relevant in a country like Spain, which is highly energy dependent, releases high quantities of greenhouse gas emissions, and consumes more energy than the mean of the European Union [34]. In order to achieve that target, a National Plan on Renewable Energy Sources 2011–2020 was produced [34].

Renewable energy sources contributed to 11.3% of the primary energy consumption, and to 13.2% of the final gross energy consumption in Spain in 2010 [34]. Their contribution to electricity gross production was 32.3% in the same year, with a 14.6% contribution of (on-shore) wind energy [34]. Wind energy was the renewable energy source that experienced greater rise between

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2000 and 2010, contributing to meeting 16% of the national electricity demand and sometimes exceeding 50% of the hourly demand in 2010 [34]. It is also expected to be the most important renewable source by 2020. However, by 2015 no offshore windfarms had been established in Spain, although a number of commercial projects in shallow and intermediate waters up to 50 m were proposed during the first years of the 2000's. Depending on the progress of wind turbine technology, wind power production potential in Spanish shallow waters was estimated in nearly 8 GW, with offshore wind energy being expected to be commercially competitive by 2020 [34].

Renewable energy sources are more environmentally sustainable than fossil fuel energy sources, including oil, coal, and natural gas, in the sense that they cannot exhaust and that they produce less quantities of greenhouse gases per unit of energy produced [33]. Renewable energy sources also pose far less risk to human health and the environment than nuclear energy. Marine renewable energy sources include wave energy, tidal energy, ocean thermal energy and offshore wind energy. However, the fact that they are more environmentally friendly and less risky than traditional energy sources does not mean they are totally harmless to the environment during their installation, operation and/or decommission phases [8]. More precisely, marine wind energy's impacts on the environment include: impacts on fauna from collisions; nuisance and displacement from noise, vibrations and electromagnetism; barrier effect; seascape impact; and habitat destruction [29]. In European settings, wind power disturbances are shown to chiefly affect some faunal taxa, namely birds (particularly raptors, migrating birds and waterfowl) and bats [1,42], and marine mammals including small cetaceans, particularly harbor porpoises (*Phocoena phocoena*), and pinnipeds, primarily harbor seals (*Phoca vitulina*) [3]. Additional environmental impacts occur from windfarm associated submarine structures (e.g. submerged power lines connecting energy production and transference sites) and coastal facilities (e.g. power stations).

Spain's marine biodiversity is one of Europe's highest, although still not known in its entirety. The variety of geological, oceanographic and biogeographical conditions determines rich, diverse and complex marine environments. To date, 1000 plant species and over 7500 animal species have been described in the country's continental platform alone [28]. Many invertebrate taxa including *Turbelaria*, *Nematoda* and sand-dwelling organisms remain poorly studied, and the biology of many others is still unknown, so even greater marine biological richness is to be expected as knowledge progresses. To adequately protect such marine biodiversity, in recent years Spain has developed a network of MPAs that has not yet been completed, but which already exceeds international protection coverage targets in the country's Mediterranean inshore and offshore waters [32]. As a result, the network can be considered reasonably well developed, with no massive increases expected.

With the renewable energy source Directive passing in the foresight [12], the Spanish Government carried out a strategic environmental assessment of the Spanish coastal waters for the installation of marine wind farms which accounted for the cumulative and synergetic impacts of individual windfarm projects on environmental values and other human marine uses [33]. The SEA was the most comprehensive study on marine and coastal socioeconomic uses and environmental and cultural values till that date. It divided the Spanish waters up to 24 nm in three zones according to their suitability to host commercial windfarms: *Suitable*, *Suitable with conditions* and *Exclusion zones*. Nevertheless, a key environmental factor, the coverage of the Spanish MPA network, has greatly increased since 2009. For example, the area covered by MPAs in the Spanish Mediterranean has experienced a five-fold rise just between 2014 and 2015 mostly due to the designation of numerous Natura 2000 sites at sea [32], making it necessary to update the assessment of the suitable areas for the installation of future marine windfarms.

The European Union's Blue Growth Strategy [14], which aims at maximizing the sustainable economic potential of Europe's seas and oceans through further developing economic activities such as aquaculture, coastal tourism, marine biotechnology, seabed mining and ocean energy, is likely to put higher pressure on already heavily pressured European marine environments [9]. Thus, this study seeks to spatially estimate the potential offshore wind power capacity to be installed in Spain accounting for the country's environmental conservation needs. More specifically, it has the following objectives:

1. Defining the *potential* (all non-excluded areas, according to the SEA) and *optimal* areas (according to wind speed, bottom depth and seabed substrate) to locate marine wind farms in Spanish waters accounting for new MPA designations;
2. Estimating the theoretical installed wind power capacity from the *potential* and *optimal* areas, and how they would contribute to the country's offshore wind energy capacity installation targets;
3. Determining whether existing commercial marine windfarm project proposals could be carried out considering new environmental restrictions.

2. Methods

The final zoning of the Spanish waters up to approximately 24 nm from the coastal straight baselines included in the SEA [33] was used as a spatial (GIS) cartographic basis for this study. The SEA represents the most comprehensive, country-wise maritime planning study to date. It considered and mapped the following socioeconomic uses and environmental and cultural values of the sea by 2009: fishing resources and activities, coastal public domain areas, biodiversity and protected areas, archeological heritage, maritime and air traffic security areas, and seascape value [33]. The final SEA layer distinguished between: 1) *Suitable zones*: zones where no likely negative environmental impacts or socioeconomic conflicts from marine windfarms were envisaged at the planning phase (SEA), without precluding individual projects' environmental impact assessments (EIAs); 2) *Suitable zones with conditions*: zones where the impacts or conflicts that were detected at the planning phase would have to be assessed in detail by specific EIAs; and 3) *Exclusion zones*: zones that should be excluded from marine windfarm development for their significant environmental impacts or conflict with other marine uses.

All MPAs designated or proposed for designation (but with a preventive protection regime) from April 2009 (publication date of the SEA) and up to the end of November of 2015 that lay within the 24 nm inshore SEA area were considered to update the *Exclusion zones* for the establishment of marine windfarms. These included 45 new MPAs: 36 marine Special Protection Areas (SPAs) designated in 2014 [36], six Sites of Community Importance (SCIs) proposed for designation in 2014 [37,38], one SCI proposed for designation in 2015 [41], one marine Ramsar site designated in 2011 [39], and one Marine Protected Area and Special Area of Conservation designated in 2011 [35]. The main characteristics of these MPAs are shown in Appendix A. Official GIS data for MPAs were collected from the Spanish Ministry of Environment's website [27], and merged in a single Spanish 'new MPA layer'. Some studies on the effects of terrestrial windfarms have suggested negative effects on fauna, especially birds and bats, up to 10 km from windfarms' boundaries [1,33], and even beyond that distance in the case of specific marine fauna [3]. Thus, applying a precautionary approach to marine windfarm development, ten-kilometer