Ocean & Coastal Management 152 (2018) 77–87

Contents lists available at ScienceDirect

Ocean & Coastal Management

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

Offshore wind energy resource assessment under techno-economic and social-ecological constraints

V. Magar*, M.S. Gross, L. González-García

Centro de Investigación Científica y de Educación Superior de Ensenada, Baja California, Carretera Ensenada-Tijuana No. 3918, Zona Playitas, C.P. 22860, Ensenada, B.C., Mexico

A R T I C L E I N F O

Article history:
Received 12 April 2017
Received in revised form
25 September 2017
Accepted 2 October 2017

Keywords:
Offshore wind energy
Resource characterization
Techno-economic constraints
Social-ecological framework

A B S T R A C T

An offshore wind energy resource assessment is presented. This includes techno-economic and social-ecological constraints. The theoretical total installed capacity is estimated using a wind climate data-set. Then techno-economic constraints are incorporated to assess the practical energy potential using water depth and proximity to high voltage transmission lines as the two limiting factors. The assessed area is the northern half of the Gulf of California, a marginal sea on the Northwestern Pacific coast of Mexico. Adding ecological constraints by incorporating natural resource systems, results in a techno-economic and ecologically viable offshore wind energy potential of 35% of the theoretical potential. Finally, social constraints are assessed by incorporating small-scale fisheries geographical information. When removing most of the fishing grounds the fully constrained potential is 2500 GW, only 13% of the theoretical wind energy potential. If areas used by only one community are included then this increases to 30% of the theoretical potential, or 5766 GW. The technical installed capacity for 6 MW turbines is 131 GW with fishing grounds exploited by at most one fishing community included, and of 52 GW for the fully-constrained problem, i.e. with no fishing grounds included. The latter is equivalent to 84% of Mexico's total energy production. Exploiting these resources would be crucial for the country's current and future sustainable development, but it is necessary to implement flexible and dynamic marine spatial plans, and include all stakeholders and regulators in the analysis and decision-making process.
© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

In 2014, the United Nations (UN) launched the 'Decade of Sustainable Energy for All (2014–2024)' initiative at the Bloomberg New Energy Finance Summit in New York. The aim of the initiative is to reduce energy poverty while reducing greenhouse gas emissions (UN News, 2014). It is accepted that the most pressing global energy policy problems are to provide equitable access to modern energy and mitigate climate change with a transition towards clean energy sources (Goldthau, 2011). By the beginning of 2014, renewable energy sources accounted for 43% (56% with large hydroelectric dams) of net additions to installed power capacity in operation and 95 developing countries had renewable energy support policies in place, up from just 15 in 2005 (REN21, 2014). However, reaching the UN targets requires additional efforts, that have led to a number of renewable energy policy revisions. Most of the policies enacted or revised during 2013 focused on the power sector, with some countries such as Mexico opening the electric market to private investment, and to independent utility-scale power producers for the first time since 1960. The opening of Mexico's energy market aims to accelerate the pace of development and deployment of the latest renewable energy technologies through projects led by the private sector. Onshore solar and wind energy, two of the most mature and easy to install clean energy technologies (despite the intermittency of the resource), are gaining access to Mexico's energy market very fast. However, it is recognized that offshore wind and tidal energy technologies, for example, have reached a high technology readiness level (TRL) as well, and coastal wind or tidal farms (at depths of 50m or less) will not necessarily incur a high penalty on levelized cost of electricity (LCOE) for wisely selected sites. It is also acknowledged that diversification of the renewable energy matrix is needed to ensure equitable energy access from emerging technologies (WECouncil, 2016).

While offshore wind and tidal energy resources are very abundant, for example, in the Gulf of California (in the Pacific

* Corresponding author.
E-mail address: vmagar@cicese.edu.mx (V. Magar).

https://doi.org/10.1016/j.ocecoaman.2017.10.007
0964-5691/© 2017 Elsevier Ltd. All rights reserved.

Northwest), this area is also one of the most biodiverse areas in the world (Enríquez-Andrade et al., 2005). The Gulf of California (GoC), also known as the Sea of Cortés, is a Gulf in both the oceanographic and the atmospheric sense. As shown in Fig. 1), the Gulf is constrained by coasts on three of its boundaries, while its lower atmosphere is constrained by the Sierra Madre mountain range in the Mexican mainland and the San Pedro Mártir mountain range in the Baja Californian Peninsula (Badan-Dangon et al., 1991). This explains why it is so rich in tidal and wind energy resources (Marinone and Lavín, 1997; Badan-Dangon et al., 1991) and in biodiversity (Enríquez-Andrade et al., 2005). Therefore, compromises need to be made between offshore renewable energy deployments and biodiversity protection. Moreover, small-scale fishing and ecotourism are some of the most important human activities in the region due to the lack of large coastal urban developments or ports – other than the port of Guaymas. Therefore, techno-economic constraints and social-ecological vulnerabilities may hamper the development of offshore renewable energy projects. However, through adequate marine spatial planning, possible conflicts and opportunities between different marine space uses can be fully analysed. Synergies can be identified and pursued, ensuring the sustainable development of the region.

There is an extensive body of literature on marine spatial planning and trade-off analysis recognizing the coupling between human and ecological systems in offshore renewable energy siting projects (Alexander et al., 2012; Tallis et al., 2010, and references therein). However, marine spatial planning usually does not consider the needs of different sectors in an integral manner (Alexander et al., 2012), except when all stakeholders are consulted and the plans consider both present and future scenarios, as well as flexible marine spatial planning strategies (Ehler and Douvere, 2009). Also, the value of ecosystem services is usually difficult to quantify and is not known with sufficient spatial resolution for local scale planning (Pendleton et al., 2007; O'Higgins et al., 2010) which can be a problem for projects with a small to medium-sized spatial footprint (Berkenhagen et al., 2010). Ecosystem-based management approaches require adequate spatial and value data (European Union, 2008), but alternative environmental and social data and models used within spatial decision support systems (SDSS) may still enable scenario analysis and user conflict resolution (Matthies et al., 2007), particularly for economic-ecological trade-off evaluations. For trade-offs to be analysed thoroughly and successfully, regulators need to be consulted as well during the analysis and decision-making process (Brown et al., 2001).

Both scientific questions and science policy issues have been investigated previously in the Gulf of California, the region of interest. Marine currents and tidal dynamics have been studied since the early 1980s (Badan-Dangon and Henderschott, 1986; Marinone and Lavín, 1997; López Mariscal and García-Cordova; Palomares-García et al., 1998; Lluch-Cota et al., 2010; Lavaniegos et al., 2012; Álvarez-Borrego et al., 1991; Álvarez-Borrego, 1983). Primary productivity and marine mammal behaviour has also been analysed in some particular areas with high populations, for example Bahía de los Ángeles and Bahía San Jorge (Ladrón-de Guevara et al., 2015; Mellink and Orozco-Meyer, 2006). Wind circulation, dynamics and climatology analysis has also been performed (Badan-Dangon et al., 1991; Gross and Magar, 2015). In relation to science policy, issues that have been addressed relate mostly to fisheries and ecosystem conservation (Aragón-Noriega, 2007; Lluch-Cota et al., 2007). The literature shows a clear lack of analysis into the possible integration of offshore renewable energy development in marine planning and policy activities in the Gulf of California. The current paper aims to address this knowledge gap, extending the social-ecological conceptual framework proposed by Ostrom (2009) to renewable energy systems, with a focus on the potential implementation of coastal (depths of 50m or less) and offshore (depths between 50m and 200m) wind farms (CWF or OWF, respectively).

The objective of this paper is to assess the offshore wind energy resource under techno-economic and social-ecological constraints. The results and recommendations, although focused principally on the case of the Gulf of California, are applicable to any coastal-offshore region of the world where offshore renewable energy exploitation is to be realized together with biodiversity protection and socio-economic development.

2. Materials and methods

2.1. Description of the study site

The study region used for the analysis is located in the Gulf of California (GoC), between Santa Rosalía - Guaymas and the Delta of the Colorado river, highlighted in the polygon in Fig. 1. The 50 m bathymetry contour line shows the coastal area limit for installation of bottom-mounted offshore wind turbines. Because the continental shelf in the GoC is very narrow, such areas are limited to coastal regions northwards of the San Luis Gonzaga - Puerto Libertad transect, and to a Sonoran coastal region around Bahía Kino, on the southern side of Isla Tiburón Island. The study area is the maritime area covered by the red polygon shown in Fig. 1. The bottom of the domain corresponds to the Santa Rosalía to Guaymas ferry route, established at the end of the XIXth century to transport passengers and goods (Romero and Gil, 1991), for example: shipping containers, petrol, chemicals and petrochemicals, cement, steel, cars, minerals and agricultural products, salt, and sulfur, among others (MEXICO NOW, 2012). Due to its extensive capacity and available infrastructure, the port of Guaymas would be well suited as an operations port for offshore and marine renewable energy projects in the region. The top of the domain extends all the way up to the Colorado river mouth, also known as the Delta of the Colorado River (DRC). This region is covered by the Upper Gulf of California and the Delta of the Colorado River biosphere reserve. The biosphere reserve starts Northwards from the San Felipe-Puerto Peñasco transect, as shown in Fig. 3. This reserve is one of the most vulnerable sites in the region, because it is the only remaining natural habitat of a number of endemic marine species.

2.2. Theoretical and techno-economic wind energy potential data

Wind resource characterization analysis is an essential tool in identifying optimal sites for development based on theoretical and practical wind power potential, with offshore wind being no exception to the rule. Wind power density (WPD),

$$WPD = \frac{\rho_{wet}}{2}\overline{|\mathbf{u}^3|} \quad (1)$$

with ρ_{wet} being the height varying (humid) air density (in kilograms per cubic meter) and $\mathbf{u}$ the wind velocity (in meters per second), is one of the most important indicators in energy resource analyses, and therefore WPD will be used here to characterize the resource potential. The overbar denotes time average, and in the case of equation (1), the average of 3-hourly velocity data from a climatologically correct wind speed dataset (Gross and Magar, 2015), the N512 UPSCALE dataset. This is the largest global climate simulation to date (Gross and Magar, 2015). The simulation was based on the HadGEM3-GA3.0 configuration of the Met Office Unified Model (MetUM) version 8.0 (Mizielinski et al., 2014), combined with the GL3.0 configuration of the JULES community land surface model (Walters et al., 2011) The 27-year period

Download English Version:

https://daneshyari.com/en/article/8060894

Download Persian Version:

https://daneshyari.com/article/8060894

Daneshyari.com