Methods for Wind Farm Siting Optimization: New England Case Study

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ABSTRACT

Two independent methods are developed to assist in determining the optimum locations for siting offshore renewable energy facilities (winds). A spatial typology, based on multivariate statistical analysis, namely Principal Components and Cluster Analyses (PCCA), identifies homogeneous marine regions based on geophysical resources and development constraints. A Technology Development Index (TDI), defined as the ratio of technological challenges faced to extract energy versus power resources available is also introduced. Both methods are applied, within a marine spatial planning framework, to Rhode Island and Southeast New England coastal waters, to determine optimum sites offshore wind turbines supported by lattice jacket structures. The methods are robust to variance in the input data and give results in good agreement with each other.

KEY WORDS: renewable energy; marine spatial planning; component principal; cluster analysis; TDI index; Rhode Island.

INTRODUCTION

Rhode Island’s Coastal Resources Management Council (CRMC) is currently leading an Ocean Special Area Management Plan (SAMP) initiative, with the objective of zoning State coastal waters to accommodate a wide variety of uses, including renewable energy development. In this effort, identification of sites for offshore renewable energy facilities (wind, wave, and in-stream tidal and ocean current) is being performed, using a marine spatial planning-based approach. Methods for siting offshore renewable energy facilities have been under development for the past two decades in Europe, but are in their early stage of development in the United States.

In this study, we present an extension of earlier work by Spaulding et al (2010), aimed at developing an objective tool for helping marine spatial planners to identify optimal areas for siting renewable energy facilities, in particular, wind farms. In the first part of the study, referred to as Tier 1, we only focus on geophysical factors, viewed as resources, or constraints, and define an objective balance between these. Tier 2, which is in progress, focuses on ecological factors (not addressed here).

The present approach, first, develops an objective typology of the water, identifying homogeneous marine areas based on energy potential and geophysical constraints. Then, in a second step, the site evaluation is made more specific to the wind farm siting by developing an index, which quantifies the area in terms of suitability for a wind farm installation. This index, which is a function of geophysical potential and constraints, is referred to as Technological Development Index (TDI) and reflects the technological cost of extracting wind resources. The lower the TDI value, the more optimum the site. This preliminary sitting approach identifies suitable or optimal sites, in terms of maximal production and minimal technological cost associated with the wind farm installation. Note that maintenance costs have not been explicitly considered, although they are significantly affected by the offshore sitting (Breton, S-P and Moe, 2009; El Thalji, I., 2009). The technologies considered in the TDI are monopile and lattice Jacket. Floating structures are not included since these were a priori not considered for the Rhode Island plan.

SPATIAL TYPOLGY BASED ON GEOPHYSICAL POTENTIAL AND CONSTRAINTS

The method defines the spatial area of interest by a group of variables, describing the area in terms of resources and constraints, and objectively identifies homogeneous sub-areas or regions. When multiple variables are considered to spatially describe a complex process, it is not trivial to extract homogeneous regions. To help doing so, multivariate statistical methods can be applied, such as Principal Component and Cluster Analyses (PCCA), which have been extensively used in socio-ecological science to regroup similar objects described by multiple variables (Zuur, 2008).

The use of quantitative analysis in spatial planning emerged in the late 1960s (Haggett, 1968) and multivariate statistical methods have since then been specifically applied to regionalization and urban and rural planning (Owen and al, 2006). Their use in marine planning, however, is still limited (Jordan, 2010; St Martin and Hall-Arber, 2008). Recently, optimization techniques using genetic algorithms have been applied to wind farm siting. Lee et al (2009) used two variables, wind speed and bathymetry, to optimize their sitting; their criteria of optimization was to maximize the energy density while satisfying the criteria of maximum depth and maximum distance to the coastline.