Renewable Energy 94 (2016) 619–628

Contents lists available at ScienceDirect

Renewable Energy

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

Offshore wind farm site selection study around Jeju Island, South Korea

Taeyun Kim [a], Jeong-Il Park [b, *], Junho Maeng [a]

[a] Korea Environment Institute, 8F-11F, Bidg.B, 370 Sicheong-daero, Sejong-si, 339-007, Republic of Korea
[b] Korea Research Institute for Human Settlements, 254 Simin-daero, Dongan-gu, Anyang-si, Gyeonggi-do, 431-712, Republic of Korea

ARTICLE INFO

Article history:
Received 8 October 2015
Received in revised form
4 March 2016
Accepted 24 March 2016

Keywords:
Marine renewable energy
Offshore wind farm
Environmental impact assessment
Site selection
GIS

ABSTRACT

This study suggests strategies for conducting an offshore wind farm site selection and evaluates feasible offshore wind farm sites in the coastal areas of Jeju Island, South Korea. The site selection criteria are classified into four categories: energy resources and economics, conservation areas and landscape protection, human activities, and the marine environment and marine ecology. We used marine spatial techniques from GIS and the investigated resources available in the country. The results indicate that offshore wind farms can be located along a wide range of the eastern and western coasts of Jeju Island, considering energy resources and economics only. However, when considering the four categories presented in this study, the number of feasible offshore wind farm sites was significantly less than when only energy resources and economics were considered. The data and analysis presented in this study will be useful for the offshore wind farm site selection around Jeju Island, and it will also contribute to minimizing the environmental impacts and reducing the social conflicts between stakeholders.

1. Introduction

In the wake of the Fukushima nuclear disaster in Japan and the concern surrounding climate change induced by human activities and fossil fuel consumption, countries worldwide continue to expand their investment in and support for renewable energy [1–4]. Since the enactment of the Alternative Energy Development Promotion Act in 1988, South Korea has gradually increased its investment in developing technology in eleven renewable energy sources, including solar power, wind power, hydrogen and fuel cells, biofuels, wastes, hydropower, and marine current power [5]. Surrounded by water on three sides of the country, South Korea has an advantage in developing marine energy sources; thus, research on renewable marine energy sources, such as offshore wind power, tidal power, wave power, and ocean thermal energy conversion, has been conducted on an ongoing basis.

Although South Korea is operating the world's largest tidal power plant with 245-MW power capacity at Sihwa Lake, construction of additional tidal power plants is being delayed for environmental and social reasons. Wave power and ocean thermal energy conversion are not yet profitable from an economic perspective and are still being researched. In contrast, the technological development of offshore wind power continues, and larger offshore wind farms are being planned [6,7]. The Korean government is moving forward with its sixth power supply plan for the construction of a 3668-MW wind power complex, which is equal to more than three nuclear power plants, with eleven wind power farms, including Southwest Offshore Wind Power (2.5 GW), Jeollanam-do Offshore Wind Power (300 MW), Hado Offshore Wind Power (150 MW), and Hanlim Offshore Wind Power (150 MW) [8]. While these offshore wind farm developments promise to assist in the effort to reduce dependence on fossil fuels and generate long-term reductions in greenhouse gas emissions, construction plans for offshore wind farm plants have been suspended in response to resident protests or environmental conflicts in South Korea [9,10].

Jeju Island, which has excellent wind resources but currently receives power from the inland, formulated “Jeju Special Self-Governing Province Wind Power Generation Comprehensive Management Plan” in 2012 to implement the long-term and well-organized development, use, and management of wind power [11]. This plan initiatives to increase output capacity to 300 MW on land and 2 GW at offshore wind farms. Several development plans have been proposed for large-scale construction of commercialized

* Corresponding author.
E-mail addresses: kimty@kei.re.kr (T. Kim), jip@krihs.re.kr (J.-I. Park), jhmaeng@kei.re.kr (J. Maeng).

http://dx.doi.org/10.1016/j.renene.2016.03.083

offshore wind farms around the Island, but most of the projects are not being advanced because of opposition from the local community and issues related to the projects' authorization and approval. For instance, Tamla Offshore Wind Power, which is the country's first commercial offshore wind power complex, plans to build ten 3-MW generators in the sea off of Hangyeong-myeon, Jeju Island. However, the start of construction is reportedly uncertain, as no consensus was reached with the residents of Hangyeong-myeon. Facing a similar situation, Daejeong Offshore Wind Power, which is located in the sea off of Daejeong-eup, Jeju Island, originally aimed to complete the installation of twelve 7-MW generators by the end of 2014. Because the local fishing cooperative and residents opposed the project, the procedure for the area's designation as a power generation district was brought to a halt. Hanlim Offshore Wind Power District is going to have 150-MW generation facilities with a total of twenty-eight 3-MW or 5-MW turbines constructed on public waters. The location is a tourist area; therefore, the Jeju Island view committee conducted a comprehensive review and concluded that the offshore wind farm would be problematic from a scenic perspective. The project is not going to receive final approval and has been pigeonholed. The Southwest Offshore Wind Power Plan, which is a 2.5-GW offshore wind farm project, was postponed due to a lack of profitability and social acceptance [12]. Similarly, offshore wind power projects are being delayed due to negotiations with residents, scenic issues, and profitability, which has created stumbling blocks for additional plans to develop offshore wind power.

Therefore, to ensure the continuous implementation of offshore wind power projects in South Korea, we need a reasonable site selection approach that considers not only social but environmental issues before choosing a site. Additionally, it is crucial to conduct a diversified and comprehensive examination of the environmental, social, and economic effects involved in selecting sites for offshore wind power projects. In this study, we suggest strategies for offshore wind farm site selection and evaluate feasible offshore wind farm sites in the coastal areas of Jeju Island, South Korea. The research will help reduce social conflicts among stakeholders and contribute to a more sustainable and eco-friendly implementation of future offshore wind power and other marine-based energy projects.

2. Method

2.1. Criteria to consider for offshore wind farm site selection

From previous studies, we can extract what is important for selecting a site for an offshore wind farm power project. The Scottish Government [13,14] conducted an empirical analysis of an offshore wind farm that was to be built in Scottish waters. The basic plan considered wind resources, water depth, ports, and power grids. As for wind resources, an important factor in selecting a site, speeds of at least 8 m/s in locations a minimum of 10–20 km away from the coast were required. Additionally, because of technological developments, it was thought that a gravity-based structure, tripod, or quadropod would make it possible to construct a wind farm in waters as deep as 40–50 m. Ports are ideal places for power generation facilities because of their resources and manpower, and the location of power grids was considered as they are required for energy transmission. Because climate change induces changes in the levels and patterns of the Scottish seas, climate change is also considered. Additionally, water resources, sediments, biodiversity, maritime view, population density, public health, cultural heritage, and marine resources were reflected in the short-term, medium-term, and long-term plans [13,14].

The Scottish government took into account various criteria for selecting a site for an offshore wind farm. However, the other studies selected criteria which were set based on the purpose for their study. Jay [15] conceptualized criteria that should be considered in choosing a site for an offshore wind farm. In consideration of its cost-effectiveness, an offshore wind farm must be located close to a power grid on land; while to prevent obstructing the sea view, it must be sited at least 12 miles (32 km) from the coast. An offshore wind farm has to maintain a certain distance from such facilities as oil and gas platforms or sea routes and should exclude any areas that involve military operations or are ecologically significant. Because positioning small facilities in multiple locations could cause a project to appear cluttered from the perspective of the utilization of the sea, the study suggests that it would be better to have a project that is mixed with other maritime activities, such as fishing and recreation. Schillings, Wanderer, Cameron, van der Wal, Jacquemin and Veum [16] performed a study in the North Sea that assessed potential areas for offshore wind power with the criteria of ship operations, marine sand mining, gas and oil drilling, existing offshore wind power facilities, submarine communication cables and pipelines, natural conservation areas, military operation areas, fishing grounds, and wildlife protection areas. A scenario was created based on the criteria, and the economic value and spatial sustainability were estimated for those areas. Punt, Groeneveld, Van Ierland and Stel [17] emphasized the importance of prudent spatial planning for the exclusive economic zone of the Netherlands. From their perspective, the researchers selected wind energy potential, water depth, and distance from land as the required factors for the quantity of energy resources, while also considering factors that could influence the ecological environment. The study further created four scenarios – profitability, protection of birds, protection of habitats, and multi-purpose indicators – to analyze the plan's sensitivity and determine the selected feasible sites.

The feasible offshore wind farm sites in the Danish Exclusive Economic Zones (EEZ) were investigated using GIS. To evaluate the profitability of each energy resource the wind energy, distance-to-coast, and contaminated/obstructed areas were considered as criteria in the site selection. In addition, the protected Ramsar wetland area, protected bird area, natural conservation area, submarine communication cables and pipelines, military operation area, radio and radar corridors, ship operation area, and scenic preservation were included in the criteria to be considered, and a buffer zone was adopted for all criteria. The annual average wind energy potential that was calculated by focusing on profitability amounted to 400 TWh, ten times as much as the Danish demand for electricity, whereas the energy potential was calculated to be less when considering the natural scenery, hazard factors at sea, and Denmark's water quality [18].

In Asia region, Yue and Yang [19] evaluated developable offshore wind energy areas in Taiwan that met such criteria as a minimum wind speed of 6 m/s at an altitude of 50 m, a maximum distance of 30 km from land, and a maximum water depth of 40 m. Scenarios were created based on GIS and, after extracting areas that disqualified for each criteria, sites were determined for installing offshore wind farms. Ports and sea routes were not considered to be feasible wind farm areas, and radar and marine archeology zones were excluded from this study due to a lack of available data. This study mentioned that a location at least 5 km from the coast has a greatly decreased influence on the view. The total wind energy potential was calculated using the output per wind power generator and the profitability was evaluated. China plans to build 30-GW offshore wind farms in its EEZ by 2030, and a related analysis has been conducted using GIS. Feasible offshore wind farm sites have been evaluated considering available technology, economics, and space utilization, while also considering the major excluded