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Lessons learnt from the evaluation of the feed-in tariff scheme for offshore wind farms in Greece using a Monte Carlo approach

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ABSTRACT

Offshore wind energy development is considered essential to meet European targets for CO_2 emissions reduction. However, offshore wind farms face not only typical risks associated with emerging technologies, but much higher uncertainties arising from various technical, political, economic and regulatory risks, most of which have been aggravated during the recent economic crisis. This is especially true in Greece where despite the investors' interest there is no progress in the realisation of offshore wind farms. The scope of this paper is to investigate the profitability range of offshore wind energy investments in Greece, taking into consideration the uncertainties faced. To this purpose, a systematic profitability analysis is performed in twelve offshore wind projects, using a Monte Carlo simulation integrated into a classical financial model for the treatment of various sources of uncertainty and in relation to the eventual variation of feed-in tariffs, as foreseen in the current legislative framework. The proposed methodological approach has proved to be a very useful tool for policy makers, enabling the simultaneous consideration of a significant number of uncertainty drivers. Moreover, the obtained results demonstrate the difficulties to propose a common feed-in tariff level for all offshore wind farms even in a small country like Greece.

1. Introduction

1.1. Background

Offshore wind is the fastest growing sector worldwide, with a total capacity of 11.1 GW already installed in Europe, in the end of 2015 (EWEA, 2016). Most of the offshore wind farms are installed in North Sea (69.4%), in the Irish Sea (17.6%) and in Baltic Sea (12.9%) (EWEA, 2016), still without any installation in Mediterranean. The leading countries are United Kingdom, Belgium, Germany, Denmark and Netherlands. By 2020 and 2030 the offshore wind capacity in Europe is expected to reach 40 GW and 150 GW, respectively (EWEA, 2009). Sooner or later, more European countries will be engaged in offshore wind energy development.

Greece is one of the most mountainous countries of Europe. The Pindus mountain range lies across the centre of the country in a northwest-to-southeast direction, with a maximum elevation of 2637 m. Extensions of the same mountain range stretch to the South across the Peloponnese and underwater across the Aegean. Greece has a huge coastline and large number of islands. Terrain complexity results to mostly deep waters and large spatial variations of wind potential.

The development of offshore wind farms faces technical uncertainties that pose a risk to the corresponding investment. This risk results in increasing investment costs, through financing and contingency issues, and can ultimately be responsible for the delay, postponement or cancellation of a project. Thus the lack of experience and the number of involved parameters impose a greater penalty to innovative projects because of the higher risks they entail for the investors. This is the case for offshore wind farm developers, due to unfavourable marine conditions, which have a strong influence on the financing and profitability of the project. In addition, the lack of sufficient data about this environment may

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induce large variations in the project's design, development and feasibility. Moreover, the large development costs and the long payback period of these projects further increase the risks and possible deviations from expectations.

During the past decades, technological improvements and the introduction of suitable support schemes have alleviated to a great extent relevant risks, leading to a rapid deployment of several renewable energies. However, offshore developments bloomed in the midst of a financial crisis and the ensuing recession which added further risks to any investment. In the particular case of Greece, the severe economic crisis was characterised by the lack of liquidity that blocked investments even in mature technologies like onshore wind. Most renewable support schemes were limited or even cancelled. One of the most successful support schemes is the feed-in tariff (FIT), but in the current situation, the variability of this mechanism creates huge uncertainties to the investors. From the national economy's point of view, overcompensation should be avoided, despite the fact that it is difficult to identify correct long-term FITs. The rapid change in technology costs and the risk to give more incentives than it is required for the healthy development of a new market should be taken into consideration. On the other hand, the unexpected and repeated changes in FIT schemes have significantly increased the level of exposure and mistrust in the industry which provokes a rise of uncertainty to the potential investors.

In Greece, today there is no prospect of implementation of offshore wind energy investments, despite the displayed investors' interest for offshore wind farms since 2005, the findings of the preliminary study of the Centre of Renewable Energy Sources for offshore wind development in 2010, and the recent enactment of offshore wind farms feed-in tariffs in 2013. The scope of this paper is to analyse the impact of all internal and external uncertain parameters on the financial profitability of offshore wind investments, in order to evaluate the existing framework. To do so, an iterative procedure is applied, using and evaluating different scenarios of feed-in tariffs combined with a randomly selected set of the examined uncertain parameters by a Monte Carlo simulation. All the parameters are modelled and classified in order to detect the degree the current fiscal conditions affect the overall project risk. The obtained results illustrate in quantitative terms not only the expected profitability of each potential project, but also the associated risk of economic failure, as well as the upper and lower limit of the financial return.

1.2. Scientific originality

Offshore wind energy attracts the attention of the scientific community due to several individualities in comparison with onshore wind energy (Bilgili et al., 2011), the increased interest of investors, the technical and economical challenges. Wind energy has established itself as a mature, clean and productive technology. However, reactions of local population, conflict with other land uses and stronger and more constant winds turn the investors' interest and the European industry to offshore installations. Today, offshore wind energy is a rapidly growing industry with huge potential and massive investor's interest (EWEA, 2016).

The economics of offshore wind and the various support policies in Europe have been revised (Green and Vasilakos, 2011), showing that government support remains essential for offshore wind due to high installation and connection costs. Only a gradual fall in costs is expected in the period to the mid-2020s (Heptonstall et al., 2012). The financial attractiveness among prospective offshore wind farms in selected North European countries has been analysed employing a simple Discounted Cash Flow model for hypothetical projects, geographical conditions and wind resources (Prässler and Schaechtele, 2012).

Europe is the world leader in offshore wind energy development and most of the global installations are established in the North Europe. European pattern on this field is considered as the reference for the rest part of the world, including USA (Snyder and Kaiser, 2009) and China. As a rather new technology with great prospects of development, there is a special interest on support mechanisms and financial issues.

In parallel, technical and financial issues related with offshore wind energy has been widely investigated. The additional challenges faced in Finland due to Arctic conditions and the required tariff support are analysed (Salo and Syri, 2014), using average estimations on the main parameters. A Geographical Information System has been used to represent the spatial distribution of levelized production cost of offshore wind energy in China, in shallow waters along the coasts of Fujian, Zhejiang, Shanghai, Jiangsu and northern Guangdong, taking into consideration mainly spatial parameters (Hong and Möller, 2011). The risk of possible influence of tropical cyclone on these regions is mentioned, without detailed assessments (Hong and Möller, 2011). Barriers and risks related to economic viability, grid connection and public acceptability in Scotland has been analysed using a specific offshore wind farm, as a representative case study (O'Keeffe and Haggett, 2012).

A first general overview of the offshore conditions for wind energy development in Mediterranean against other European Seas has been reported by Gaudiosi since 1994 (Gaudiosi, 1994). In this connection, the aim is to present a holistic approach on the treatment of uncertainties in the preliminary stage of financial feasibility for offshore wind energy projects in a Mediterranean country. The proposed methodology is applied for twelve representative case-studies in Greece to evaluate the recently established feed-in tariff scheme. For this purpose, a Monte Carlo approach is combined with a classical financial model, to calculate the feasibility of offshore wind energy projects. However, this approach constitutes a useful tool for policy makers, developers, investors and banks, for the assessment of projects, evaluation of support schemes and decision making.

Two are the main contributions of this work: Firstly, the effective integration into the financial assessment of an offshore wind farm of all uncertain parameters that might influence its profitability through the proposed Monte Carlo approach. Although the method is increasingly implemented to deal with the uncertainty characterising physical phenomena and modern systems in todays' highly complex economic and technological environment, the novel element of this paper is the selection and modelling of the parameters relevant to the performance and profitability of offshore wind farms. To the best of our knowledge Monte Carlo simulation is used mainly in the study of technical aspects of wind farms. A second novel element of the present paper is the exploitation of the resulting risk measures in the design and the assessment of effective support mechanisms. The proposed Monte Carlo technique could be widely applied in any case, regardless the stage of development and the number of parameters under investigation.

1.3. General framework for offshore wind energy in Greece

Wind installed capacity in Greece, has reached 2151.7 MW at the end of 2015 with 172.2 MW added in 2015 – all of them onshore (EWEA, 2016). In the National Renewable Energy Action Plan of Greece, it is foreseen that 7500 MW of wind capacity is required by 2020, of which 300 MW offshore (Ministry of Environment Energy and Climate Change of Greece). This target for wind energy installations is very difficult to be reached with the current annual rates of development, mainly due to local reactions, lack of financing, bureaucracy, grid constraints, spatial planning issues and