ARTICLE IN PRESS

Renewable and Sustainable Energy Reviews xx (xxxx) xxxx–xxxx

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Compound real options valuation of renewable energy projects: The case of a wind farm in Serbia

Dragan Loncar[a], Ivan Milovanovic[b], Biljana Rakic[c], Tamara Radjenovic[c,*]

[a] University of Belgrade, Faculty of Economics, Belgrade, Serbia
[b] Renewable Energy Expert, Belgrade, Serbia
[c] University of Nis, Faculty of Economics, Nis, Serbia

ARTICLE INFO

JEL classification:
C41
D81
G11
G31
Q42

Keywords:
Renewable energy sources
Electricity generation projects
Wind farm
Binomial tree
Capacity factor
Feed-in-tariffs

ABSTRACT

Renewable energy sources have become a very important issue due to environmental and sustainability concerns. In addition, most renewable energy electricity generation (RES-E) projects are characterized by considerable uncertainty and sequential decision-making. These projects' net present value (NPV) is very often close to zero, which renders them a good candidate for the application of real options valuation methodology of investment project appraisal.

This paper examines the real options valuation of a potential onshore wind farm project in Serbia. The binomial tree model spans a 15 year period consisting of a 2 year investment period and a 13 year operating period, the first 12 years of which are protected by Feed-in-Tariffs according to local renewable energy regulations. The authors examine a multi-phased compound (nested) path-dependent real option consisting of mutually exclusive options - a sequential option to invest as well as expand, repower, contract and abandon options. Volatility, which is calculated by means of a Monte Carlo simulation according to the logarithmic-present-value-returns approach, shows predominant sensitivity to the capacity factor simulated with the rescaled Weibull's probability distribution. The final binomial tree results show that the proposed sequence of options increases project value by transforming higher risk and lower return in the initial discounted cash flow model, to lower risk and higher return in the RO model.

This paper contributes to the existing literature in at least two ways: it presents in-depth analysis of the real option application to the RES-E project and provides decision-makers with sophisticated tool for improving strategic thinking, capital budgeting and decision-making processes.

1. Introduction

In the last decades, there has been increased interest in sophisticated strategic valuation tools and techniques of capital investment projects and portfolios used for valuing uncertainties, as well as managerial flexibility in the decision-making process during the project life cycle and the post project, i.e. operational period. One such technique is found in the Real Options Valuation (ROV). ROV significantly overcomes limitations inherent in the discounted cash flow (DCF) approach expressed in the NPV (Net Present Value) metrics [1]. In addition, ROV improves decision tree analysis (DTA), which is one of the preferred tools in corporate strategy and planning. ROV may be applied to a wide range of projects such as R & D, infrastructure, pharmaceuticals, exploration of natural resources, etc. [2]. Furthermore, ROV is suitable for the various renewable energy project assessments [3–37], which will be elaborated on in more detail in Section 2. Apart from the fact that revenues in the RES-E projects are partly hedged against risk by governmental subsidy measures, deregulation of the energy markets (mainly gas and electricity) in many countries constitutes one of the reasons that makes application of real options in the energy sector, including RES-E, even more important than was the case in past.

According to Copeland and Antikarov [38], ROV is the most applicable when the following three conditions are met: (1) high uncertainty about the future, (2) high room for managerial flexibility, and (3) in the case of NPV without flexibility near zero. In that regard, the applicability of the ROV approach in RES-E projects can be assessed as follows:

(1) In RES-E projects, typically subsidized by various support measures, the level of uncertainty of project revenues tends to be more modest than high. The present value of the project is mainly driven

* Corresponding author.
E-mail address: tamara.radjenovic@eknfak.ni.ac.rs (T. Radjenovic).

http://dx.doi.org/10.1016/j.rser.2016.11.001
Received 6 November 2015; Received in revised form 7 October 2016; Accepted 1 November 2016
Available online xxxx

Please cite this article as: Loncar, D., Renewable and Sustainable Energy Reviews (2016), http://dx.doi.org/10.1016/j.rser.2016.11.001

by technological uncertainties embedded in the variability of both the capacity factor and electricity market price upon expiration of the subsidy period. In the countries where the respective renewable technology has already reached "grid parity," i.e. market electricity price, this revenue uncertainty is present in the project cashflow from the very beginning.

(2) In addition, there is significant room for managerial flexibility in RES-E projects, due to the variety of real options which could be reasonably applied during project development phases (sequential invest, defer, abandon), as well as during operation (expand, repower, contract, abandon).

(3) Static NPV is often close to zero in RES-E projects, but with a reasonable application of real options, they can be transformed to profitable projects if the previous two conditions are fulfilled. NPV of RES-E projects occasionally is deeply out of money, so that even the application of real options cannot make it profitable, as demonstrated by Milovanovic [39] in the case of large ground mounted solar photovoltaics (PV) projects in Serbia, referring to given assumptions and types of real options applied in the model.

The authors have decided to assess the application of ROV in a greenfield onshore wind farm project considering the following present conditions in Serbia: (a) the FiT (Feed-in Tariff) system has been established, with express commitment to RES development through National Renewable Energy Action Plan (NREAP); (b) the installation of RES-E power plants with a total capacity of 1.092 MW[1] through 2020 (from that figure, 500 MW goes to wind) have been planned; (c) there exists a lack of medium to large size competitors in the RES-E market; (d) negotiations for joining the EU were initiated in 2014; and (e) the electricity market has been recently liberalized both in the industrial and residential sectors. At the same time, this paper can provide useful ideas to companies willing to invest in Greenfield wind projects in Serbia.

This paper is divided into six sections, with accompanied subsections where applicable. To give an overview, Section 1 contains an introduction, followed by a literature review in Section 2, related to the previous studies concerning RES-E and ROV. Section 3 explains the renewable energy electricity market in Serbia with a focus on wind potential. Section 4 discusses risks in wind electricity generation. Section 5 is the most comprehensive, wherein the numerical potential of a wind farm project in Serbia along with detailed explanations of the ROV technique are presented. The conclusion is given in Section 6.

2. The literature review

Electricity generation by means of RES has become of major importance with heightened concerns about environmental issues. As a result, many countries all over the world are using different instruments and measures to encourage investment in renewable generation projects. There are several types of RES-E support schemes in active use worldwide: Feed in Tariffs (FiT), Quota Obligation Systems and Tradable Green Certificates (TGC), Investment Subsidies, Fiscal measures, Tendering schemes and Feed in Premiums (FiP). The increasing need for RES-E and the presence of government support measures have been widely studied issues among researchers in recent years. The enhanced investment in RES-E projects depends primarily on social (public) acceptance [29–34], and the attendant concerns about the increased costs attached to public promotion of these resources [35–37].

Zografakis et al. [32] investigated factors for the social acceptability of the RES on the island of Crete and based on the results, concluded that households have a positive attitude toward the implementation of RES and are willing to pay on average 17,88€ per person per annum to this end. Other studies [30,31] investigated public acceptance of energy technologies in the Dutch province of Utrecht and reached the conclusion that citizens have stronger preferences for RE technologies, especially for offshore wind energy and biomass energy. The results also revealed two main factors shaping public preferences: knowing (prior knowledge about the energy technologies) and caring (environmental awareness) [30].

Despite the positive preferences in favor of RE technologies, some studies revealed public sensitivity toward externalities, especially landscape disturbance and modifications in the case of wind turbines in Germany [29,34] and Italy [33]. Additionally, concerns were raised about the efficiency of government support measures [37], i.e. regulatory and policy options [23–28], and the overall costs and benefits attached to renewable electricity. The studies demonstrated that the benefits of RES promotion are higher than the costs in Spain [35] and the EU member states [36] in the case of wind and hydro, while this is not the case for bioenergy, solar PV, and other RES-E. These studies emphasized two main benefits from RES-E utilization - lower CO_2 emissions and fossil fuel savings.

Lee and Shih [27,28] investigated the application of ROV in renewable energy policy evaluation. According to these authors, the government has five options available when considering the promotion of RE development: to grow, to abandon, to contract, to expand, and/or to switch. This approach for evaluating RE development policy ensures that policy actions are based on the government's political, macroeconomic and technological development considerations [28, p. 2194], thus providing the most efficient usage of fiscal resources. The results obtained indicate that ROV is very effective at measuring "how policy planning uncertainty including managerial flexibility influences RE development" [27, p. S67].

Barroso and Iniesta [24,25] examined the real regulatory options (public support and subsidies) in Denmark, Finland, Portugal and Germany. Their results reveal that the choice of the renewable energy support measures has an impact on the project valuations: the public prefers the FiP over the FiT system, whilst the expanded NPV value stands the highest in Finland and the lowest in Portugal. Moreover, Zhang et al. [23] proposed a policy evaluation model for solar PV power generation which demonstrated that the reduction of the subsidy rate could be effective from the government's and the investors' perspectives. Additionally, Ritzenhofen and Spinler [26] studied the change of FiT regime for onshore wind investments and demonstrated that the later change to the FiT regime would have a low impact on the investment decision, while switching to market regime might divert or halt the investments. These approaches enable policy makers to recognize in advance the long-term economic consequences of given public support schemes.

Apart from these studies, extensive literature exists which examine the application of ROV in planning, design, construction and operation of different RE projects in countries all over the world. Venetsanos et al. [3] recommended a framework based on the ROV for the appraisal of wind energy projects under the uncertainty of the deregulated energy market drawing from the case of Greece. They valued the option to defer, to expand and to abandon, and their results showed the benefits of ROV in valuing uncertainty. Another study by Davis and Owens [4] considered the external uncertainty regarding the market prices of fossil fuels for the valuation of RE technologies using a continuous RO model, and found that RE technologies are economically attractive from the RO perspective. Similarly, Siddiqui et al. [6] also examined the uncertainty in fuel prices for valuing the renewable energy research, development, demonstration and deployment in the U.S. but by using binominal lattice model, since it better reveals the economic intuition underlying the decision-making process, and demonstrated that the options value is significantly greater than when using the DCF approach.

Wang and Min [5] applied ROV at both the planning and opera-

[1] In this paper the symbol "." denotes digit grouping (thousands), while the symbol "," denotes decimal comma.