Energy 73 (2014) 751–761

Contents lists available at ScienceDirect

Energy

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

Evaluating China's biomass power production investment based on a policy benefit real options model

Xingwei Wang [a,*], Yanpeng Cai [b,c,**], Chao Dai [d]

[a] Key Laboratory for Water and Sediment Sciences of Ministry of Education, School of Environment, Beijing Normal University, Beijing 100875, China
[b] State Key Joint Laboratory of Environment Simulation and Pollution Control, School of Environment, Beijing Normal University, Beijing 100875, China
[c] Institute for Energy, Environment and Sustainable Communities, University of Regina, 120, 2 Research Drive, Regina, Saskatchewan S4S 7H9, Canada
[d] College of Environmental Science and Engineering, Peking University, Beijing 100871, China

A R T I C L E I N F O

Article history:
Received 9 April 2014
Received in revised form
20 June 2014
Accepted 21 June 2014
Available online 14 July 2014

Keywords:
Biomass power production
Economic evaluation
Policy benefit model
Binomial tree model
Real options approach
Uncertainty

A B S T R A C T

In this study, a policy benefit real options model was developed to evaluate biomass power production investment in China. A method based on the cumulative probability was proposed using binomial decision tree calculations for the exercising of options in order to evaluate the optimal investment timing. Two scenarios were analyzed to identify the optimal investment strategy with/without the consideration of revenue from certified emission reduction (CER). Uncertainties in straw purchased price, government incentives, and technological improvements were considered. The results showed that it was not optimal for immediate investment in biomass power production in China. Given full government subsidy, the thresholds of straw purchased price for scenarios 1 and 2 are 213.55 and 218.87 RMB/ton, respectively, while the current straw purchased price in Chinese market is 220 RMB/ton. The investment of biomass power production would be executed at 2022 and 2028 with/without the consideration of revenue from CER in the current situation in China if there are no government incentive to encourage motivation, respectively. The conclusion could provide useful information for power enterprise decision-makers on whether and when to invest a biomass power production in China in an uncertain environment.

1. Introduction

Utilization of biomass has attracted increasing attention across the world due to growing concerns over depletion of conventional energy reserves, as well as the growth of associated environmental and greenhouse gas emissions [1–4]. Biomass is one of the most important renewable energy resources in a prospective renewable and sustainable energy future since it is considered carbon-neutral [5,6]. This is especially crucial for many newly prosperous countries such as China. According to this country's "The 12th Five Year Plan for Renewable Energy Development", electricity generated by biomass will have reached a total installed capacity of 13 GW by 2015. This value will have been double by 2020, supposing to account for 4% of the total energy consumption [7,8]. In order to achieve this goal, China's National Development and Reform Commission (NDRC) and many other relevant governmental agencies have developed a series of policies and regulations, such as *Temporary Measures for Revenue Allocation of Addition Price on Electricity of Renewable Energy Resource, Interim Measures On Renewable Power Surcharge Collection and Allocation, and Temporary Measures for Management of Subsidy Fund of Utilizing Straw Energy Resources* [8]. However, the process for identifying potential strategies and decisions related to biomass power production are complex due to the diversity in specific biomass features and the differences in biomass-based technologies [9]. For example, the outdated generation technology, high cost of straw collection, storage, and transportation still hinder the development of biomass power generation in China [10]. Decision-makers and energy managers are thus facing numerous challenges in generating biomass utilization strategies and policies. Particularly, whether and when should power enterprise invest a biomass power production plays a vital role in biomass related decision-making in a region. Therefore, it is desired to provide a comprehensive analysis and evaluation of biomass power generation under a complicated and volatile environment in China.

Previously, numerous studies were undertaken to investigate and evaluate biomass power generation in China based on various

* Corresponding author. Tel./fax: +86 10 58809850.
** Corresponding author. State Key Joint Laboratory of Environment Simulation and Pollution Control, School of Environment, Beijing Normal University, Beijing 100875, China.
E-mail addresses: wangxingwei0812@gmail.com (X. Wang), yanpeng.cai@bnu.edu.cn (Y. Cai).

http://dx.doi.org/10.1016/j.energy.2014.06.080
0360-5442/

methods. For example, Zhao and Yan [11] assessed the factors of strengths, weaknesses, opportunities, and threats of the biomass power generation industry in China through using the SWOT (Strength, Weakness, Opportunities and Threat, in which “S” and “W” are internal factors, while “O” and “T” are external factors) analysis method. Wu et al. [12] analyzed economic characteristics of biomass gasification and power generation in China regarding the associated costs for investments, electricity generation, and waste treatment. Liu et al. [13] systematically analyzed temporal and spatial patterns of crop stalk resources, evaluated potential bioenergy of straw resources, and explored possible pathways of identifying straw-based energy strategies in Inner Mongolia, China. Zhang et al. [14] estimated the cost of straw-based power generation through the adoption of the method of life cycle analysis. The results showed that straw cost took the largest share among the operation cost. Also, the basic causes of the high cost included many factors such as straw characteristic, mismatch between demand and supply, immature technology, inappropriate project planning and low motivation of farmers in selling straw. Sun et al. [15] displayed a spatial planning framework to identify the appropriate development areas for biomass utilization at a regional scale. The analyses showed a clear picture of how to identify the locations of biomass power plants to minimize the cost and maximize the supply security of feedstock. The methods discussed above analyzed the current situation of China's biomass power production development and conducted corresponding economic evaluation. However, they were mainly based on the conventional cost-profit evaluation approach when conducting economic evaluation, such as discounted cash flow method (DCF) with the criterion of net present value (NPV). These methods have the defects when dealing with biomass power production investment evaluation due to the inherent characteristics of biomass power production investment in China: (1) the investment costs are mostly irreversible; (2) the timing of biomass power production is at the discretion of the firm; (3) the high uncertainty of payoff; (4) the scarce cumulative information, technology gap, and high investment risk; (5) the strong influence of national policy on biomass power production investment [16,17]. The reason is that the decision under multiple NPV criteria is normally based on static data and information, and cannot provide updated information for supporting dynamic decision-making regarding the investment that need to consider uncertainties in the future [18].

Comparatively, a number of studies were conducted on the evaluation of renewable energy generation project planning using real options approach (ROA). For instance, Boomsma et al. [19] adopted an ROA to analyze investment timing and capacity choice for renewable energy projects under different support schemes. Kumbaroglu et al. [20] presented a policy planning model, which integrated the learning curve information of renewable power generation technologies into a dynamic programming model that featured real options analysis. The model evaluated investment alternatives in a recursive manner and had the ability to delay an irreversible investment outlay that could subsequently affect the prospects for the diffusion of different power generation technologies. Kjærland [21] applied ROA to evaluate potential hydropower investment opportunities in Norway. The approach explained investment behaviors in a way that was not captured by NPV approach. Moreover, the analysis showed that such an ROA based approach could give insight into the value of investment opportunities and aggregate investment behavior in this industry. Lee and Shih [22] presented a policy benefit evaluation model, which incorporated cost efficiency curve information on renewable power generation technologies into an ROA framework. The method was used to quantitatively evaluate the policy value provided through developing renewable energy in the face of uncertain fossil fuel prices and policy-related factors. The results demonstrated that the renewable energy development policy with internalized CO_2 emission costs was an appropriate policy from sustainability point of view. Martínez-Ceseña and Mutale [18] proposed an advanced ROA based methodology for supporting renewable energy generation projects planning. The results showed high-expected profits for projects could be achieved through an advanced ROA based approach. Reuter, Fuss and colleagues [23] employed an ROA method to investigate specific policy characteristic of renewable energies and their associated uncertainties in a stylized setting through explicitly taking into account market effects of investment decisions. Detert and Kotani [24] analyzed the changing investment environment for renewable energy with ROA and explored its potential in developing economies through studying the case of Mongolia under uncertain coal prices. The aforementioned studies discussed the optimal strategy for renewable energy project investment in an uncertain environment through using ROA. Compared with DCF approach, the real options approach (ROA) can possibly postpone judgment on an investment to an appropriate time and thus is suitable for the evaluation of biomass power production with considerable uncertainties. It has the following intrinsic properties to deal with: (a) the irreversibility of the investment, (b) the uncertainty in cash flows of the future investment, and (c) the timing of the investment flexibility [25]. The decision rule of real option method offers enhanced flexibility in decision-making. The investor could postpone judgment on an investment and wait for favorable circumstance and thus provide new opportunities [26], which is in line with the actual management. However, due to the specific characteristics of biomass resource in China, such as scattered distribution, plenty of varieties, obvious seasonality, difficult to collect, storage and transport, and low effective utilization [27], few previous studies were conducted for handling complexities and uncertainties in China's biomass power production investment evaluation and then provided decision-support for the investor through ROA.

Therefore, the objective of this study is to establish a policy benefit real options evaluation model to analyze China's biomass power production investment. A method based on cumulative probability will be proposed through using binomial decision tree calculations for exercising the option in order to evaluate the appropriate investment timing. Uncertainties in straw purchased price, government incentives, and technological improvements will be considered. The results will be particularly useful in providing appropriate investment timing for investors under uncertainty, and also provide information for power enterprises' biomass power production investment evaluation and related policy-making in China.

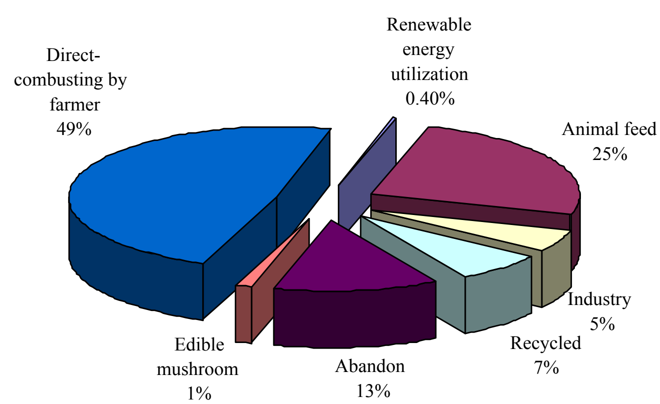

Fig. 1. The structure consumption of straw in China.