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Energy Procedia 138 (2017) 1099–1104

Energy Procedia

www.elsevier.com/locate/procedia

2017 International Conference on Alternative Energy in Developing Countries and Emerging Economies 2017 AEDCEE, 25 - 26 May 2017, Bangkok, Thailand

Risk Management in Biomass Power Plants Using Fuel Switching Flexibility

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Abstract

Thailand's energy consumption from alternative sources continues to increase in recent years. This is largely due to the Thai government's policy in promoting alternative energy development in all sectors, especially in biomass energy which accounts for a significant share of the total amount of alternative energy. Moreover, over the next 20 years, Thailand wants to double the amount of energy from biomass sources from 2,812 MW to 5,570 MW by 2035. In order to meet this ambitious target, the Thai government provides financial incentives through a program called Feed-in-Tariff so as to attract private developers to implement alternative energy projects. As for biomass power plants, however, a major risk is an input biomass price, which can be fluctuated according to season and availability in the area where the project is located. This paper is therefore to present a method that can help mitigate the risks stemming from biomass price fluctuation using a flexible design called "Fuel Switching Flexibility (FSF)". The FSF is a design concept that takes advantage the notion that fuels for biomass projects can be from several sources. Then, project managers have the option to select the appropriate sources of input materials for the energy production of the project. Valuing the biomass power plants embedded with the FSF can be done with real option analysis. The results of the study showed that projects with FSF have increased in its financial values, without the help of government in handing the financial subsidy. However, the project with only the FSF may, during a certain period, still face financial difficulty, and this is why the government subsidy is still needed for alternative energy projects like biomass power plants.

Keywords: Risk management; Biomass power plants; Fuel Switching Flexibility (FSF).

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10.1016/j.egypro.2017.10.126

1. Introduction

Due to energy shortage, global warming, and climate change, there is a marked shift of energy use from conventional fossil fuels to a more environmentally friendly source. One of such energy sources is renewable energy (RE), which can provide universal access to energy. It also helps create new business opportunities, reduce the external energy dependency, in which Thailand imports a large amount of fossil fuels from the foreign countries, and, at the same time, contribute to the reduction of greenhouse gas emissions [1]. These benefits of renewable energy have been acknowledged by many countries around the world, which has abundant natural resources that can turn into a new source of energy. Like many countries around the world, Thailand has tried to increase the use of energy from renewable sources. At policy levels, the Energy Policy and Planning Office (EPPO), a government agency responsible for the country's energy policy, set out a plan aiming at increasing the country's energy security through a more diversified portfolio of energy produced (i.e., increasing the amount of energy from renewable sources). That plan was named Alternative Energy Development Plan or AEDP.

However, obstacles to renewable energy implementation are many. For example, high costs of technology, subsidy policies, and input uncertainties for some renewable sources are commonly cited as the main obstacles to promote renewable energy developments. These obstacles are especially evident in the realm of solar power plants and biomass power plants, which are currently facing an increase of projects' cancellation. In addition, if we look further at capacity shortfall, it was found that, over the next 20 years, Thailand wants to double the amount of energy from biomass sources from 2,812 MW to 5,570 MW by 2035 [2]. Therefore, there must be underlying problems in promoting the development of biomass power plant projects (BPPPs). And, there is a good chance that, under the current government policies, the target of renewable energy from biomass will not be met. This provides opportunities for this research to investigate into the cause of slow progress in the implementation of the BPPPs.

To solve Thailand's energy shortfall, this paper proposes a new method tool that can help mitigate the risks stemming from biomass price fluctuation using a flexible design called "Fuel Switching Flexibility (FSF)". In this study, the simulation methods were evaluated the flexibility value in BPP projects. Simulation approaches generally have two main processes. The first involves forward projections of underlying risk variables. Monte Carlo simulation is generally used to perform this task. The second involves determining the optimality of decisions at each time step in a backward fashion. This step can be done using dynamic programming techniques such as least squares regression (referred to as Least-Squares Monte Carlo (LSM) method by [3] and parameterizing boundary method [4] for estimating an expected continuing payoff (i.e., the value of not exercising an option at this time step). The goal of this backward algorithm is to compare and choose, at each time step, the maximum value between: (1) an immediate payoff if exercised now and (2) an expected continuing payoff, if exercised later. The main advantage of simulation approaches is their flexibility in modelling of underlying risk variables that can follow any type of stochastic processes, that is, geometric Brownian motion or GBM is no longer a requirement for modelling the underlying risk variables.

2. Biomass price modelling in biomass power plant projects

In the BPPPs evaluation, a biomass price will be projected in the future in order to simulate a cash flow to calculate the project value by using a stochastic process. This process is defined as set of random variable, which can be represented as $\mathbf{X} = \{X_n : n \geq 0\}$ or $\mathbf{X} = \{X_n\}$, where X_n is state of the random process at time n, and its initial state is X_0. Brownian motion (also called a Weiner process) is one of the most important basic notions of stochastic processes. Brownian motion originally refers to the random motion observed under microscope of pollen immersed in water. It is also a continuous-time Markov stochastic process whose increments are independent, no matter how small the time interval. Specifically, if $Z(t)$ is a Brownian motion, then any small change in z, dz, corresponding to a very small time change dt, satisfies the following conditions: (More detailed treatment of stochastic process can be found in [5] and [6])

i. The relationship between dz and dt is given by $dz = \varepsilon_t \sqrt{dt}$, where ε_t is a normal distributed random variable with a mean of zero and a standard deviation of one.
ii. ε_t is serially uncorrelated, that is, $E(\varepsilon_t \varepsilon_s) = 0$ for $t \neq s$.

However, in practice, GBM in its standard form does not well represent the price fluctuation of commodity. Therefore, next section may modify the GBM process to contain some essential effects such as mean reversion and seasonality so as to achieve a more realistic representation of biomass price used in this study.

First, a mean reversion trend is a simple characteristic of a commodity price in a market. The most popular mean reversion model is the Ornstein and Uhlenbeck ('O-U') process. In this model, biomass price is assumed to be on average and moved toward a long-term mean. Second, as agricultural commodity whose prices fluctuate according to season and availability, the prices of biomass behave exactly in the same manner. This research accordingly acknowledges this characteristic of biomass prices, and models its prices using a stochastic model as shown in Eq. (1):

$$dx = \kappa(L - X_t)dt + \sigma dz + \gamma \cdot \sigma \cdot \sin(\frac{2\pi(i)}{12}) \quad (1)$$

where X_t is the price of biomass at time t, L is the long-term mean of commodity prices, κ is the speed of mean reversion, γ is the seasonal movement value, and i is the operated month of project.

3. The Fuel Switching Flexibility (FSF) concept

Flexible fuel switching is a new tool that can be used to mitigate the risk stemming from higher-than-expected fuel costs, which may have a negative impact on the project's financial value. This concept is a design concept that takes advantage the notion that fuels for biomass projects can be from several sources. How the conditions and factors leading to the decision to switch the fuel from one material to another can be modelled based on the FSF concept as presented in Fig. 1.

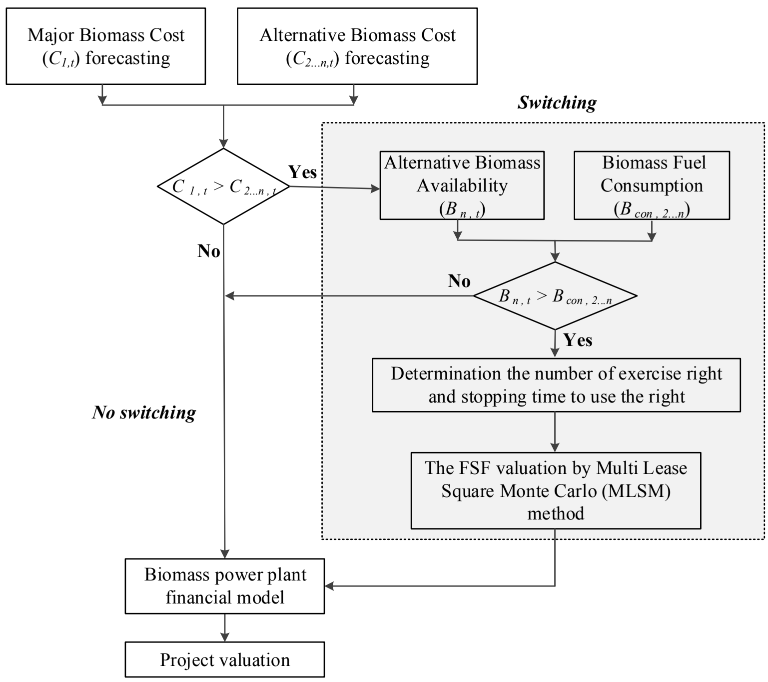

Fig. 1. Fuel Switching Flexibility (FSF) model.

From Fig. 1, The first step of the FSF model is to compare between major biomass cost ($C_{1,t}$) and alternative biomass cost ($C_{2...n,t}$) at time t, where n is number of material types, If $C_{1,t}$ is cheaper than $C_{2...n,t}$, it will confirm that no FSF is available. On the other hand, if $C_{1,t}$ is more expensive than $C_{2...n,t}$, switching of current material to alternative materials that have lower cost will be considered.

Next step, the FSF characteristic about a number of rights to switch the biomass source for each year is determined. Under the consumption that the BPPPs can storage the biomass source for one year, the number of switching right can determined from dividing a biomass availability in year ($B_{n,t}$) by a monthly biomass consumption ($B_{con,n}$). The number obtained indicates the maximum period of month for each year in which the alternative materials to produce the electricity can be used as an energy source.

After the number of switching right is determined, then, the stopping time or time to optimally switch biomass source can be determined. However, determining stopping time is not simply. This is because the future event is unforeseeable. Therefore, we cannot directly compare the value between switching now and keep this right to use in the future. One way to solve this limitation is to determine by using advance methods such as a backward dynamic programming with Multi Lease Square Multi Carlo (MLSM) method to identify the stopping time.

Finally, after we know the conditions about a number of right and stopping time, the new data set are used as the input in the BPPPs financial model and project evaluation is analyzed accordingly.

4. The related parameters in the FSF model

There are three main parameters dealing with the FSF implementation: biomass cost, alternative biomass availability, and biomass fuel consumption. This section will give relevant definitions and equations for determining each parameter.

4.1. Quantitative availability

Quantitative availability is the amount of biomass sources that can be collected to the projects [7], [8], [9], [10]. One way to determine the biomass quantitative availability or $B_{n,t}$ is to compute by using a modelling method. For example, in 2001, Voivontas [11] have proposed biomass quantitative mathematical model: however; this equation neglect the collection efficiency effect. It results are therefore overestimated. To solve this limitation, this section is adapted the biomass quantitative availability to a more suitable model by adding the collection factor as illustrated in Eq. 2.

$$B_{n,t} = \sum_r a_{n,t} \cdot y_n \cdot t_{s,n} \cdot eff_{c,n} \tag{2}$$

Where n is a type of biomass source.
t is an operated time at time year, t.
y_n is a biomass production yield, ton /rai year.
$\sum_r a_{n,t}$ is a total biomass cultivated area, rai.
r is a region.
$t_{s,n}$ is a seasonal biomass production, month
$eff_{c,n}$ is an efficiency of biomass collection.
$B_{n,t}$ is a biomass availability in year of each biomass sources, ton/year

4.2. Biomass cost

Second parameter using in the FSF consideration is a biomass cost ($C_{n,t}$). It can be defined as the money to pay for a biomass source per a unit of produced electricity (W). This parameter is determined as shown in Eq. 2.

$$C_{n,t} = \mathrm{X}_{B_{n,t}} \cdot E_{cap} \tag{3}$$

Where $C_{n,t}$ is a biomass cost at time *t*, baht/kWh.
$X_{B_{n,t}}$ is a price of biomass source at time *t*, baht/ton.
E_{cap} is a biomass energy capacity, ton/kWh.

4.3. Biomass fuel consumption

Final parameter that deals with FSF is a biomass consumption in the BPPPs. This parameter is defined as the amount of monthly biomass consumption, which is a function of a lower biomass heating value, an installed capacity, a plant efficiency, and an operated time as illustrated in Eq. 3.

$$B_{con} = \frac{I_C \cdot O_t}{1,000 \cdot LHV_n \cdot \eta_p} \quad (4)$$

Where B_{con} is a monthly biomass consumption, ton/month. I_C is an installed capacity, kW.
O_t is an operated time, second/month. LHV_n is a lower heating value, kJ/kg.
η_p is a biomass availability in year of each biomass sources, ton/year.

5. Results of the case example

5.1. Case example project: 1200 kW biomass power plant

Summary of the case example is presented as shown in Table 1. All of these parameters are important parameters to evaluate the project under the FSF model by using MLSM method.

Table 1. Summary of case example conditions.

Conditions of case example			
Major biomass source	Slab rubber tree	Minor biomass availability	5,608 ton/year
Major biomass cost	0.5028 to 3.8548 baht/ kWh	Minor biomass consumption	1,015 ton/month
Minor biomass source	Oil palm fiber	Number of exercise right	5 per year
Minor biomass cost with 3% inflation	1.2640 baht/ kWh	Number of exercise	12 per year

5.2. Results of the probabilistic BPPPs valuation

There are two significant increasing values in the case of the FSF: the expected and the minimum project value as shown in Table 2. First, the FSF can improve the project value from negative in case of no subsidy to positive project value which increase about 4.1 million baht. Second, the FSF enhances the project value of the worst situation ([12], and [13]) from -24.61 to -13.25 million baht. However, the project itself may experience financial difficulty because the minimum value is still a negative value. Therefore, the subsidy pattern is used to solve this problem. Two subsidy patterns are determined: the current Thailand policy named as Feed-in Tariff (FiT), and the combination of the FSF and the Biomass Price Guarantee (BPG) as presented by [14]. As presented Table 2, it was found two significant results. First, under the FiT mechanism (see Table. 2), the expected project NPV is 86.86 million baht and the minimum and maximum are all positive values, 65.67 and 108.55 million baht, respectively. Although the FiT policy can surely guarantee the profit in the BPPPs; however, The FiT needs to a lot of money to subsidize [15] about 90.26 million baht. Second, the combination of the FSF and the BPG can better mitigate the risk of the project being unprofitable. More importantly, this pattern use the minimum governmental subsidy about 4.70 million baht.

Table 2. Summary of case example under no subsidy conditions.

Subsidy policy	Expected project value (Million, baht)	Minimum project value (Million, baht)	Maximum project value (Million, baht)	Governmental subsidy
No Subsidy	-3.43	-24.61	18.25	0
FSF	0.70	-13.25	17.70	0
FiT	86.86	65.67	108.55	90.29
FSF + BPG	5.40	1.83	18.99	4.70

6. Discussion and conclusion

This paper presents the FSF for biomass power plant projects (BPPPs). The FSF is a new way for mitigating the risk from biomass price fluctuation in the BPPPs using Risk Flexibility Analysis or RFA theory. The main process of the FSF is divided into two parts: (1) risk modelling in biomass power plant projects, and (2) risk mitigation algorithm using Fuel Switching Flexibility (FSF). Using the case example, the characteristics of risk of biomass price are modeled using the concept of stochastic modelling with two behaviors: mean reversion and seasonal fluctuation. Then, the combination of the new proposed FSF and the already proposed BPG not only guarantee the profitable project for the investors but also help reduce the cost of the governmental subsidy.

7. Acknowledgement

This work was supported by Walailak University Fund.

References

[1] Bartolomeu F, Jorge C, Paula F. The use of real options approach in energy sector investments. Renewable and Sustainable Energy Reviews 2011;15:1491-7.

[2] The Department of Alternative Energy Development and Efficiency; Alternative Energy Development Plan: AEDP2015. Available at < http://www.dede.go.th/ewt_w3c/ewt_dl_link.php?nid=43412>

[3] Schwartz S. The Stochastic Behavior of Commodity Prices: Implication for Valuation and Hedging. Journal of finance 2006;52(3): 923-73.

[4] Andersen L. A simple approach to the pricing of Bermudan swaptions in the multifactor LIBOR market model. Journal of Computational Finance 2000);3(2):5-32.

[5] Vose D. Risk Analysis: A Quantitative Guide: Wiley; 2008.

[6] Dixit RK, Pindyck RS. Investment under Uncertainty: Princeton University Press; 2012.

[7] Chau S. Biomass resources assessment for power generation: A case study from Haryana state, India. Biomass and Bioenergy 2010;34,: 1300-08.

[8] Rodrigueza LC, May B, Herra A, O'Connella D. Biomass assessment and small scale biomass fired electricity generation in the Green Triangle, Australia. Biomass and Bioenergy. 2011;35:2589-99.

[9] Kemausuor F, Kamp A, Thomsen ST, Bensah EC, Østergard H. Assessment of biomass residue availability and bioenergy yields in Ghana. Resources, Conservation and Recycling 2014;86:28-37.

[10] Lourinho G, Brito P. Assessment of biomass energy potential in a region of Portugal (Alto Alentejo). Energy 2015;81:189-201.

[11] Voivontas D, Assimacopoulos D, Koukios EG. Assessment of biomass potential for power production: a GIS based method. Biomass and Bioenergy 2001;20:101-12.

[12] Martínez-Cesena EA, Mutale J. Application of an Advanced Real Options Approach for Renewable Energy Generation Projects Planning. Renewable and Sustainable Energy Reviews 2011;15:2087-94.

[13] Locatelli G, Invernizzia DC, Mancinib M. Investment and risk appraisal in energy storage systems: a real options approach. Energy 2016;104:114-31.

[14] Sampim T, Kokkaew N. Modelling of government support in biopower plant projects: The case of Thailand. Energy Procedia 2013;52:525-35.

[15] Pita P, Tia W, Suksuntornsiri P, Limpitipanick P, Limmeechockchai B. Assessment of Feed-in policy in Thailand: Impacts on national electricity prices. Energy Procedia 2015;79:584-89.