International Journal of Engineering & Technology, 7 (3.7) (2018) 464-466

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Economic Feasibility of Rice Straw based Power Generation in Malaysia

S.M. Shafie*, Z. Othman, N. Hami

School of Technology Management and Logistics, College of Business, University Utara Malaysia, Sintok 06010 Kedah, Malaysia
**Corresponding author E-mail: shafini@uum.edu.my zakirah@uum.edu.my , norsiahami@uum.edu.my*

Abstract

Malaysia provides a potential in utilising rice straw for electricity generation. However, its implementation is still far away due to the information leak on the financial aspect for local conditions. This paper evaluates the economic feasibility of rice straw life cycle in electricity generation, starting with rice straw collection to electricity generation in Malaysia. For an assumption of 20 years, the cost of electricity generated (COE) is between RM0.72/kWh and RM0.53/kWh for 20 MW to 500 MW respectively. A sensitivity analysis on financial feasibility shows that the most influential parameter to NPV is the sales price. The result from the study will help policy makers obtain the right information regarding the economic potential of rice straw as a fuel in electricity generation in Malaysia.

Keywords: *Economic; Rice straw; Power generation; Malaysia*

1. Introduction

Biomass resources create a great potential in sustainable energy development. Recently, the world biomass consumption in electricity generation shows an increasing pattern. However, biomass energy from ASEAN countries only contributes 4.8% from the world consumption [1]. The market price of biomass resource is an important factor for effective use and successful implementation of biomass energy in this region [2]. The unavailablity of price information of using biomass has led to a high level of precariousness in the monetary value of GHG credits that would be needed to sustain the installation [3].

The boundaries setting affects the output result, some studies begin with the delivery feedstock at the conversion plant [4]. A number of studies have considered harvesting and handling cost, logistic costs for biomass delivery and storage, capital cost etc., but their scope is based on the local parameters that are well-suited with their country [5, 6]. Even though many studies found the prospects of biomass power generation from the economic point of view, the biomass resource availability varies amongst the countries. Therefore, the local conditions' specific planning is needed for the economic growth [7].

The biomass total cost is dependent on local conditions such as fuel cost and labour cost [6, 8]; hence, the economic feasibility should be performed on localised conditions. In many instances, biomass electricity production is conducted following the Europian context. However, very limited researches focused on the economic aspect on paddy residue. The economic factors such as fuel cost, investment cost and market price have become the key indicators for pursuing the successful development of renewable energies [9].

The Ministry of Energy, Green Technology and Water Malaysia established on 9 April 2009 aims to conserve the natural environment and resources, which minimises and reduces the negative impact of human activities. Under the energy sector, different types of programmes are listed to encourage the development of green technology in Malaysia.

Presently, many ongoing projects based on biomass resources are conducted in such a way to provide a long-term solution to Malaysia's energy needs and to promote a sustainable development. Until 2012, the total capacity of electricity generation from biomass-based power generation is 253.85 MW (S.M. Shafie et al., 2012), including for personal mill consumption. However, rice straw is still not consumed as a fuel in electricity generation and Malaysia still lacks the economic aspect on rice straw-based power generation. Nevertheless, paddy residue creates a vast potential in power generation based on the availability of supplies.

Therefore, this study aims to evaluate the economic analysis on rice straw life cycle electricity generation, which will help in determining the feasibility of this project's implementation in Malaysia. The detailed analysis involves the process in the system boundary, starting from rice straw collection until power generation. The cost of electricity (COE), NPV and also the payback period are calculated for variation of plant capacity from 20 MW to 100 MW. The significance of COE and fuel cost to the different plant capacities is determined and compared with the application of incentives available in Malaysia. This simple and detailed economic analysis can provide a guideline for Malaysia and other countries in supporting the financial decision process.

2. Collected Data and Methodology

The scope of the study is presented in the Figure 1, starting with rice straw production and ending with power generation. Life cycle costs involve the capital cost, operating cost, maintenance cost, feedstock cost, and salvage cost for each process shown in Figure 1.

The data derived from the literature, report and interview session are used in determining the economic feasibility of rice straw combustion in Malaysia. In this study, data has been collected from the Northern region area, which applies the collection of rice straw.

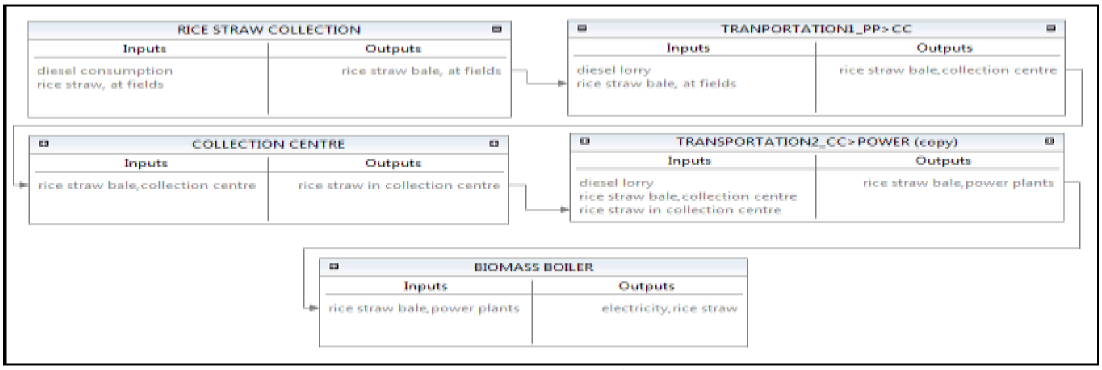

Figure 1: The scope of study

2.1 Power Plant Generation Cost

The plant capital cost includes the equipment, building constructions and land area.
The total plant capital cost for circulating bed combustors and boilers is calculated using Equation 1.

CCPG=5060 (PPC)-0.073 (1)

The production costs involve the component of labour cost, maintenance cost and overhead cost. The number of labour required for the power plant process is derived from Equation 20 [4] and its result is obtained from Equation 2 in this article. The average salary is RM3125 for Northern areas [10]. The maintenance and overhead costs are 2.5% and 2% of the total plant capital cost [4]. The total plant cost (TPC) for the power plant generation process is calculated based on Equation (2).

TPC=CCPG+LCPG+MCPG+OCPG (2)

2.2 Rice Straw Collection Cost

Rice straw collection cost involves the components of machinery, fuel, labour and twine costs. The
total annual machinery costs are the summation of fixed cost and operating cost.

2.3 Transportation of Rice Straw Cost

The total transportation cost CT1 includes the cost required for conducting the overall process of moving out the rice straw bales to the collection centre.

CT1= ((0.105*F*daT1/ LT1) + (CPT1)) (3)

The transportation cost of rice straw to power plant is derived from Equation 11. The driver's cost depends on the distance travel, which is RM4 per km. A lorry weighing 3.5 tonnes or is 40' in length is used to transport the bales [11, 12]. The bale capacity per truck is 36 bales. The location of the power plant is assumed to be at the nearest coal power plant available.

CT2=(((0.27*F*daT2)+(CD*daT2))/LT2) (4)

2.4 Collection Centre Cost

The collection centre is aimed to maintain the quality of rice straw bales at a desired level. It is assumed that the collection centre is available at the current location of rice straw collection under the MADA management. The centre of unit is assumed as the location of collection centre (storage). The assumption is that the paddy cultivating area is treated as a whole with only one collection centre in the centre. Since the rice straw collection area of the power plant is circular, therefore the cost of rice straw collection can be written as a function of the radius [13].

CCC=(CA,CC/WCC)×(1/1-DML) (5)

3. Results and Discussion

The preparation cost includes the three processes: rice straw collection, collection centre and transportation. Figure 2 shows the operating cost for each process. The transportation cost gives the significant impact of about 60 % to the total operating preparation cost.

Approximately 83.4% from the transportation process cost is from TC2. This cost can be reduced by putting the nearest power plant location to the collection centre. Reducing the distance of TC2 can reduce the fuel cost up to 25%, which is RM59.04 per bale available at the power plant gate. However, TC1, which is the cost of rice straw bales transported from the paddy fields to the collection centre, only contributes 16.6% for 20 MW up to 29.3% for 500 MW to the total fuel cost.

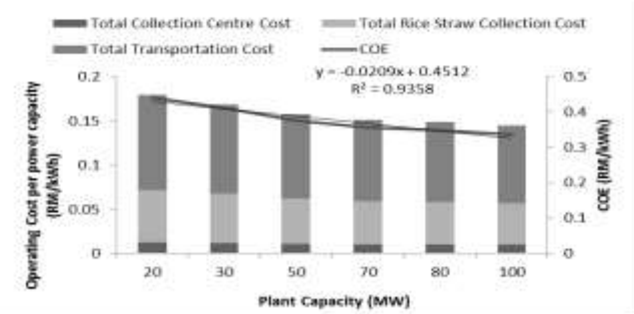

Figure 2: Operating cost for each process

Plant capacity has a large influence in the economic feasibility, which can be an offset to the price of biomass (M. Uris, J. I. Linares, & E. Arenas, 2014). Figure 2 illustrates the operating cost and COE in the function of plant capacity. Increasing the plant capacity reduces the operating cost per kW and also the cost of electricity generation (RM/MWh). The pattern follows the previous study in Canada [5] due to the economic scale in the production system. The same argument [14] shows that a large-scale plant capacity offers a better economy than smaller plants, without the need for financial support. More than half of the operating cost is contributed by the transportation sector; rice straw collection contributes 33% and the rest comes from the collection centre cost. This result is similar with the study by [15], which indicates that the transportation cost contributes 57% and storage cost 10% to the total production cost. The reduction of COE is about 0.248% per MW plant capacity increase.

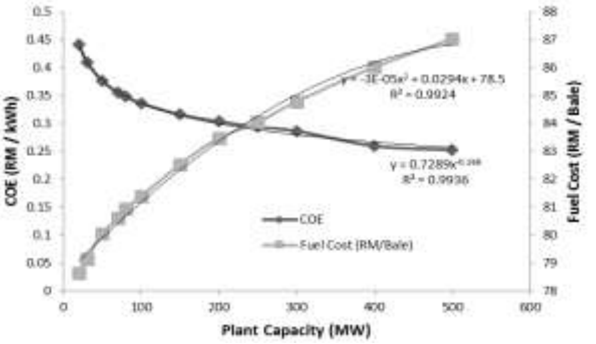

Figure 3: Relationship between plant capacity with fuel cost and COE

Figure 3 shows the relationship between plant capacity with fuel cost and COE. The COE parameter indicates the reduction pattern when the plant capacity is increased, while the fuel cost shows the other way. As biomass fuel per unit capacity depends on the capacity of the plant facility, there is a significant variable cost component related to the plant size [3]. This is similar to the result obtained from biomass gasification for power generation in Canada, where COE decreases significantly as plant capacity increases [5]. According to Gonçalo Rendeiro et al. [16], the feasibility of biomass use increases when the output is greater than 10 MW. To obtain the profit from selling the electricity, the plant size should be designed with 500 MW or greater than that based on the lower COE obtained compared to the purchase price from TNB (Tenaga National Berhad) at RM0.2125/kWh. The fuel cost is RM78.27 per bale available at a 20 MW plant capacity. It can go up until RM87.03 per bale at a higher plant capacity size (500 MW). These costs include all the costs involved in the process from collection until arrival at the plant gate. Since the transportation sector dominates the total fuel cost, this increases the plant capacity and the fuel cost. The most influential component for COE is the capital cost or investment cost. This is identical to the results obtained from the rice straw-based power generation in China. The result concludes that the total investment cost causes a major problem in creating a higher power generation cost [8]. However, this cost will reduce over time. Increasing the plant capacity can reduce the cost of electricity generation by 0.08% to 3%. A small plant capacity has a huge reduction compared to a large plant capacity.

4. Conclusion

The life cycle cost model includes the process of rice straw collection, collection centre cost, transportation and power generation. Among these, the transportation cost gives a significant impact of around 82.5% to the total operating cost. The calculated electricity generation costs are between RM0.72/ kWh and RM0.53/kWh for 20 MW to 500 MW, respectively. The reduction of COE is about 0.001% per MW plant capacity increase. Due to the high cost of the total operating and capital costs, COE is greater than the purchase price from TNB. However, COE can be equivalent to the purchase price from TNB when the plant capacity is greater than 20 MW. The most influential component for COE is the capital cost or investment cost. However, this cost will reduce over time. The payback period for 70 MW is 6.5 years and the annual cash flow is RM13.5 million. The sales price variation is the most significant to NPV.

Acknowledgement

This research was financially supported by the ministry of higher education Malaysia (frgs-13260/2015). We thank the reviewers and associate editor for their comments which have improved this manuscript.

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