Energy xxx (2016) 1–8

Contents lists available at ScienceDirect

Energy

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

Palm biomass strategic resource managment — A competitive game analysis

J.P. Tang [a, *], H.L. Lam [a], M.K. Abdul Aziz [b, 1], N.A. Morad [b, 1]

[a] Centre of Excellance for Green Technologies, University of Nottingham Malaysia Campus, Jalan Broga, 43500 Semenyih, Selangor, Malaysia
[b] Centre of Lipid Engineering and Applied Research, Universiti Teknologi Malaysia, 81310 UTM, Johor Bahru, Malaysia

ARTICLE INFO

Article history:
Received 16 February 2016
Received in revised form
26 July 2016
Accepted 30 July 2016
Available online xxx

Keywords:
Palm biomass
Supply chain
Game theory
Nash equilibrium
Competition
Procurement strategy

ABSTRACT

There are plentiful of palm biomass but these resources are not always being fully utilised. Palm biomass are plentiful; yet their utilization are far from reaching their potential. From the perspective of biomass industry players, especially of the bio-energy industry, there are primarily three factors affecting their business decision: (i) constant and good quality supplies, (ii) process efficiency, (iii) market demand and price. The strategy considerations that respond to these factors are based on other players' competition, plantation output, mill output, logistics matter, government policy and weather. In order to model a real situation in a particular palm plantation area, game theory approach is adopted in analysing and identifying the best strategy for the biomass industry owner. Given that every player tends to act according to their own self-interest for profit maximization, this is thus a non-cooperative game study. The case study in this paper is modelled on two industry players, two oil mills and two plantations. Nash equilibrium is achieved through analysing the best strategy. The strategy selected by the player will lead to the most favorable and positive outcome regardless of whatever decision made by the opponents. In other word, by analysing this scenario using game theory approach, an optimal non-cooperative strategy can be determined. For the future works, it can be applied into the decision support framework for the biomass industry management team.

1. Introduction

Oil palm industry is a significant economic backbone of tropical countries such as Indonesia, Malaysia, Thailand and etc. Worldwide crude palm oil production has increased steadily from year 2014 to year 2015 (Table 1). In Malaysia, it is currently the fourth largest contributor to the national economy, accounting for approximately 8% of the country's GNI per capita and 6% of Malaysia's GDP [1].

As at December 2014, there are 5.39 million hectares of oil palm planted area in Malaysia, occupying nearly three quarters of the country's agricultural land, which is 14% of the total land area of the country [23]. The entire area has produced 19.67 million tonnes crude palm oil in 2014 and accounted for 39% of world palm oil production [24]. Being such a large agricultural sector in Malaysia, oil palm industry has simultaneously generated vast amount of surplus palm biomass waste, which has constituted approximately 85.5% of biomass in the country, with an average of 53 million tonnes each year and is even projected to rise to 100 million dry tonnes by the year of 2020 [42]. Generally, the solid biomass wastes come directly from oil palm plantations in the form of harvested trunks and pruned fronds, and also from the palm oil extraction mills, such as empty fruit bunch (EFB), mesocarp fiber and palm kernel shell (PKS). These biomass wastes are in turn being used either in plantations or mills. For instance, the fronds, trunks and EFB are often left in the plantations for mulching purposes or to be decomposed naturally as nutrient replacement, whilst mesocarp fiber and PKS are utilised in palm oil mill as in-house fuel for generating steam and energy. Given its abundant availability, oil palm biomass is particularly regarded as a valuable alternative for energy regeneration in Malaysia. There are a plethora of researches on the relevant field, such as the optimisation of biomass, in order to convert it into a variety of value-added products [32].

Biomass supply chain constantly faces challenges and hurdles in its management, ranging from supply quality, transportation route, handling issue, market demand, and not least the world economy trend. The ever changing situation in biomass supply chain requires

* Corresponding author.
E-mail address: tang.jiang.ping@gmail.com (J.P. Tang).
[1] kebx3tjn@nottingham.edu.my.

http://dx.doi.org/10.1016/j.energy.2016.07.163
0360-5442/

Table 1
Crude palm oil production by country [11].

Country	Year 2014 (metric tonnes)	Year 2015 (metric tonnes)
Indonesia	33,000,000	33,000,000
Malaysia	19,879,000	20,500,000
Thailand	1,800,000	2,200,000
Columbia	1,110,000	1,130,000
Nigeria	970,000	970,000
Other	4,673,000	4,805,000

innovative ideas to provide a better and profitable solution. Therefore, research in this field needs to be constantly update to reflect the real world crisis and adopt to new technologies and model approaches. In palm biomass supply chain, most of the research are focused on plant processes and technologies optimisation. However, the whole palm biomass supply chain is a dynamic system where other non-technical factors should be considered and feed into the decision making system for an improved optimisation method. This paper focused on the strategies simulation on the palm biomass supply chain which take precedence of technical optimisation on plant process. As our knowledge, any changes in technologies or processes would incur high cost in the whole supply chain. Therefore, systematic strategy analysis beforehand will minimise the risk and cost of further capital investment.

The dynamic research in biomass supply chain has contributed to remarkable progress in the aspect of decision making process. The most recent development focus on software based supply chain planning and simulation. For instance, biomass storage or plant location are optimised and proposed [44] to obtain maximum profit and minimum cost [3] within a specific biomass resource region. CyberGIS [18] is able to accept multiple input parameters in biomass supply chain problem such as yield, locations, area and costs to provide a cost effective supply chain configuration in a specific region. Meanwhile, OPTIMASS [21] is another software that is able to optimise biomass supply chain depending on 3 different applications. These are all current biomass optimisation facilities, new facility location suggestion and optimal configuration of conversion facilities. The results generated by these software can be used to investigate the decision of new biomass region development by government or private sectors. However, this paper argues that the methods mentioned above are merely targeted on a single party analysis and assumed the simulated decision as the best and optimal option without taking the dynamics of competition and the opponents' strategies into consideration – which is precisely the pivot and the foremost concern in the overall biomass supply chain. Therefore, this paper proposes to adopt game theory in filling the gap of biomass supply chain analysis.

This paper aims to veer in a new direction for the oil palm biomass industry to focus on the sustainable oil palm biomass procurement as a premise for further optimization process. It should be first recognized that despite of its vast availability nationwide, procurement of palm oil biomass at regional level is nonetheless a challenge for those external biomass processing plants. Stiff supply competition is inevitable especially for whom do not own plantations. They do not merely strive for local biomass supply for their own plants and business, but also facing competition from external buyers from different states who come to procure the biomass. Irregular biomass supply, which is contingent upon oil palm harvest cycle and yield, can further aggravate competition amongst the industry players [42]. Additionally, the quality of biomass that is largely affected by surroundings moisture might considerably impact the subsequent process and cost before it can be utilised in the plant. BELCA [17] and BCI [40] methods can provide an insights of biomass material characteristics before it is ready for the plant. All of these aspects ought to be taken into consideration in measuring and identifying the best strategy to ensure sustainable palm biomass procurement.

2. Problem statement

Strengthening technology, process optimisation, supply chain optimisation and product market diversification are typically the main emphases within oil palm biomass industry. From the perspective of biomass plant entrepreneurs in particular, these facets deem to be closely affiliated with the profitability. Intensifying technologies and equipment can undoubtedly improve the efficiency of new biomass processing technology to produce reliable and higher value products, yet it would at the same time incur higher cost on the production cycle [13]. While process optimisation also aims to increase efficiency, its focus is primarily on enhancing existing process without adding to the cost and thus maximising profit. Supply chain optimisation emphasizes on the performance and improvement the supply chain structure and operation by looking into alternate sourcing, supply route management, regional collection hub positioning, and effective handling method, wherein cost is the key performance metric [47]. In fact, all of these technical approaches (Table 2) attempt to enhance their competence in their own sphere; yet they might not necessarily contribute to higher profit or to serve the plant owner best interest. Furthermore, given that biomass is commonly considered of no economic value [25] while processing such by-products does incur production cost, transportation cost and storage cost [7]; therefore, entrepreneurs might not find it economically viable.

Above all, biomass industry is competitive, particularly in terms of security and sustainability of biomass supply. In order to gain a competitive advantage over the other competitors, recognition of their interests and moves are important to gain leverage in getting the most cost-effective biomass supply [14]. Instead of merely focusing on increasing efficiency of processing biomass, it is equally crucial to shed light on sourcing strategy for effective procurement within such a competitive environment. Ultimately, strategic procurement would be a complement to the optimisation steps stated above and further enhance the overall efficiency.

3. Methodology

This paper adopts game theory approach in analysing Malaysia current competitive biomass industry, wherein multiple players are involved, often with conflicting objectives. In terms of procurement, they compete among each other to acquire the most cost-effective biomass supply and to maximise profit. In this context, the strategic form is the most appropriate method to quickly analyse each possible outcome of the described scenario, considering that all competitors make their decisions simultaneously. All possible strategies from every competitors are listed out while the outcomes for each possible combination of choices are also defined.

Table 2
Comparison of biomass supply chain analysis approach.

Feedstock	Analysis approach	Reference
Multiple biomass	Database setup	[33]
Multiple biomass	Stochastic programming	[2]
Wood chips and straw pellets	Logistics analysis	[43]
Multiple biomass	Network design	[46]
Empty fruit bunches	Optimal allocation	[10]
Multiple biomass	Network design	[41]