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Potential of Biomass to Resource as An Action to Mitigate Transboundary Haze In ASEAN Country

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Transboundary haze is one of the major environmental issues in Southeast Asia for the last three decades. The haze has not only affected the countries within the region but even beyond because of the impacts on environmental concerns with greenhouse gas (GHG) emissions and biodiversity thus challenging international attempts to address these issues. Land clearing and burning activity is a significant contributor to smoke in the atmosphere during the haze season.This study aims to investigate the economic benefits through conversion of forest biomass and palm biomass, the two main sources of peat fire to medium and higher value products i.e power and bioethanol. The outcomes of this study will provide farmers and policy makers to view the biomass as a source of 'wealth', not 'waste'.

1. Introduction

For decades, the countries of Southeast Asia, especially Singapore and Malaysia suffer from the attack of transboundary haze caused by forest fires and open burning in Indonesia. Most of the forest burning happened on the Sumatra Island and Kalimantan province in Indonesia, and some remote area in Sabah and Sarawak in Malaysia. The small and medium enterprise and local farmers practice open burning of the surrounding forests and biomass of pulp, paper, and palm oil plantations to clear space for expansion. The condition of uncontrolled forest fires getting worse with the dry weather of El Nino climate phenomenon and carbon-rich peatlands. Smoke is carried by monsoonal winds most frequently spread to Malaysia, Singapore, the south of Thailand and the Philipines, causing a significant deterioration in air quality of those countries. In 2002, all 10 South East Asian countries signed an agreement to combat the issue through greater monitoring and encouragement of sustainable development, but efforts carried out by the governance have been limited. Given the environmental damage and human health risks, these fires need to stop immediately. One solution to clearing the biomass without fire may be to harvest it and use it for value-added resources.

The rationale is that the creation of value for the burnt biomass shall provide the impetus to consider the biomass as a source of wealth to be translated into a sustainable practice of economic harvesting. Therefore, the paper first provides an introduction to biomass, their availability in ASEAN and the potential of biomass to value-added resources. It is followed by an comprehensive review on the scientific studies and research on the biomass conversion to various resources, including power and bioethanol This paper then discusses the two potential technologies of converting biomass into heat and power as well as bioethanol as one of the promising strategies to mitigate the transboundary haze pollution encountered by the ASEAN countries in recent years. Case studies with economic analysis are also presented for possible extension into detailed studies later.

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2. Potential of biomass to resources

Biomass refers to any organic, decomposable matter derived from plants or animals available on a renewable basis. Biomass residues that generated in the forests, fields or plantations are the major contributor to forest fire which caused haze in Southeast ASEAN. These residues are abundant and in dry seasons become very dry with high potential of catching fires from very small flames or even burning ambers like cigarette butts that could lead to raging fires and massive haze. On the other hand, Sumatra and Kalimantan possess *large* areas of peat forest, which is highly combustible during dry season. Therefore, the problem is further compounded in peat forests where a lot of biomass exists underground and once fire starts, it becomes very difficult to control. In this study, we focus on the utilisation of biomass generation in plantation, specifically the oil palm plantation biomass.

2.1 Oil palm plantation biomass

Oil palm is one of the world's most rapidly expanding equatorial crops. Approximately 85 % of world’s crude oil palm is supplied by Malaysia and Indonesia (Sulaiman et al., 2011). Malaysia has approximately 5 million ha of palm oil plantation in year 2011, covered a 15 % of total land area (MPOB, 2014). The oil palm has a lifespan about 200 years with the economic life up to 25 years. Peak crop yields are achieved from the age of 9-18, and gradually decline thereafter. Conventionally, a felled oil palm tree, consisting of a large amount of trunk and frond, are often shredded and buried in the field to be turned into organic fertiliser. Nevertheless, due to the cost constraints, some small and private estate holders practise open burning to clear the land, as it is the cheapest mean for land clearing. There are some utilisations of trunks and fronds as source material for plywood production but its uptake is not consistent due to uncertain economic values of the raw materials primarily due to logistic cost. At the time of reporting, it is estimated that 65 % of Malaysia’s total oil palm trees ranged between the age of 9 - 20 years, while another 26 % is approaching the end of yielding age of 20 - 28 years old (MPOB, 2014). Approximately 1.3 million ha of Malaysia’s oil palm plantation is at the felling age. A felled oil palm tree consists of 70 % of trunk, 20.5 % of frond, 6.53 % of leaflets and 5.03 % of others, as shown in Table 1 (Khalid et al., 1999). Based on the statistical data of old oil palm plantation area, it is estimated that 109 million t of biomass can be obtained from Malaysia old oil palm plantation, with 53.39 million t of trunk, 20.80 million t of frond, and others.

Table 1: Composition of an old oil palm tree (khalid et al., 1999)

Biomass composition	Average weight (kg)	Weight percentage (%)	Estimated dried weight (kg/tree)	Dried weight (t/ha)
Trunk	1,507.50	70.00	301.50	41.07
Leaflets	145.00	6.53	58.00	7.69
Frond	452.50	20.50	117.70	16.00
Spears	42.75	1.92	9.40	1.28
Cabbage	44.50	2.00	4.50	0.60
Inflorescence	134.50	1.11	6.30	17.56
Total weigh	2,217.50	100.00	497.30	84.20

The chemical composition of the forest biomass and oil palm plantation biomass are shown in Table 2. Among the palm plantation biomass, the oil palm trunk (OPT) and oil palm frond (OPF) are the main focus for the comparison of biomass characteristic. The properties of empty fruit branch (EFB) are also presented in Table 2 as the comparison with the other types of biomass. The properties of biomass are compared in the proximate analysis, ultimate analysis, and lignocellulosic content. In the proximate analysis, OPF is found to have the highest moisture content (16.00 %) as compared to the OPT and EFB. The ultimate analysis measured the elemental contents for carbon, hydrogen, oxygen, nitrogen and sulphur (C, H, O, N, S). It is valuable indicators to energy processes and gases emissions during combustion of the resource material. Comparisons were made with the elemental composition of the EFB, where the highest amount of H and N are found in 6.44 % and 2.18 % respectively. In term of the lignocellulosic content, EFB also has highest amount of cellulose (57.80 %), while similar lignin and hemicellulose content of each biomass. The higher heating value (HHV) of the biomass also compared, where EFB has the highest value of HHV with 20.54 MJ/kg, while both trunk and frond has slightly lower HHV then the EFB, with 17.27 MJ/kg and 17.28 MJ/kg respectively

Table 2: Properties of oil palm plantation biomass versus empty fruit branch.

	Oil Palm Plantation Biomass		Empty Fruit Branch (EFB) [b]
	Oil Palm Trunk [a, b]	Oil Palm Frond [c,d]	
Proximate analysis (wt% dry basis)			
Moisture content	8.34	16.00	4.68
Volatile matter	79.82	83.50	76.85
Fixed carbon	13.31	15.20	5.19
Ash	6.87	1.30	18.07
Ultimate analysis (wt% dry basis)			
C	40.64	44.58	46.36
H	5.09	4.53	6.44
O	53.12	48.80	38.91
N	2.15	0.71	2.18
S	n.a	0.07	0.92
Lignocellulosic content (wt% dry basis)			
Cellulose	45.90	50.33	57.80
Hemicellulose	25.30	23.18	21.20
Lignin	18.10	21.7	22.80
HHV (MJ/kg)	17.27	17.28	20.54

a. Oil palm biomass (www.bfdic.com); b. Guangul et al., 2012 ; c. Abnisa et. al., 2011; d. Abdullah and Sulaiman, 2013

2.2 Conversion pathway of biomass to products

Conversion of biomass generated on the forest, fields or plantations could overcome the issue of haze that caused by forest fire. In general, the approaches for transforming biomass resources to products and energy or biofuels involve thermochemical, biochemical, and physical conversion processes. The product derived from biomass can be categorised into three main types based on the economic value, namely the low value product, medium value product, and high value product. Low value products such as compost require very low investment cost and simple conversion technologies, but the product value is relatively low. Heat and power product from biomass are considered as medium value product while the biofuel and biochemical product require high investment cost and the product value is highest among the three categories.

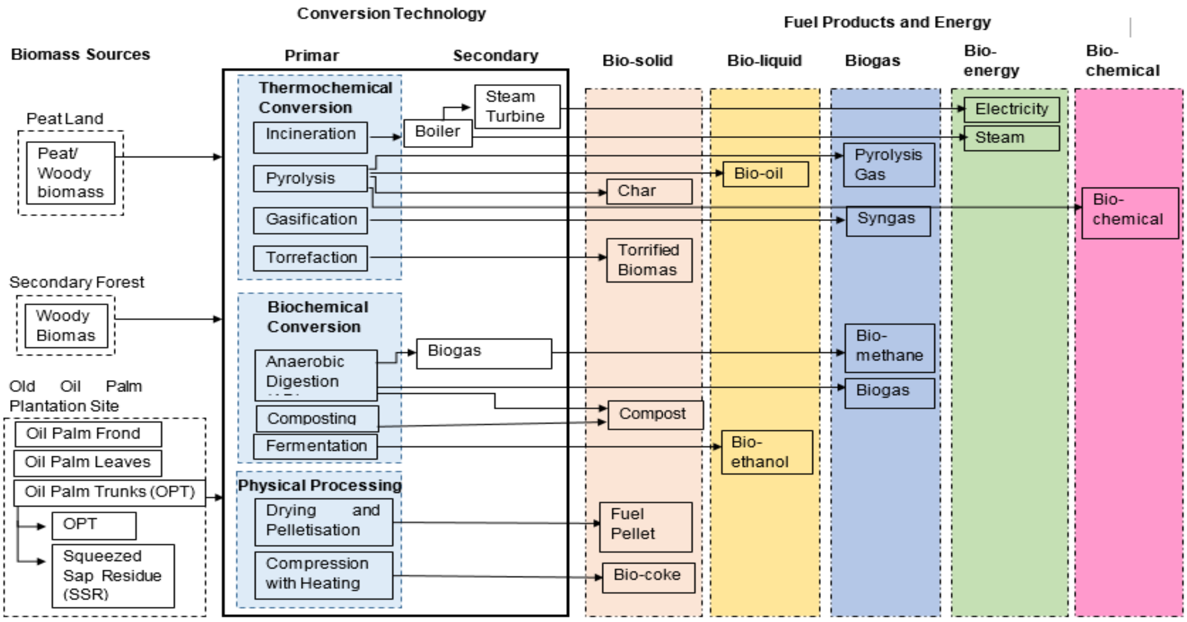

Figure 1: Conversion pathway of biomass to resources.

3. Case studies: Economic Potential of Biomass to Power and Bioethanol

Conversion of biomass on the field in forest or plantation into value-added product such as power and bioethanol can potentially play a role in an effort to reduce the resulting haze conditions from slash and burn practices. There are competing uses for biomass resources because of their economic and environmental value for a variety of purposes. Biomass material can be potentially be used to generate power, heat, steam, and bioethanol, which potentially offer high economic returns to the farmers.

To explore the economic potential of biomass-to-resources, two case studies on biomass-to-power and biomass-to-ethanol are incorporated in this section with the suggested feedstock capacity of 2,000 t of biomass daily. Net present value economic analysis with equity and debt corporate financing method are applied in the case studies to analyse the economic profitable levels of biomass-to-resources.

3.1 Biomass to Power Generation

Malaysia starts utilised biomass to power generation in year 2003, where a 7.5 MW integrated biomass co-generation plant was established in Sahbat, Lahad Datu, Sabah by the Felda Global Ventures Holdings Bhd (FGV). The power plant used EFB as the feedstock, generate heat and power for demands within the company including the CPO refining , kernel crushing plant, hotel, office and residential. The project is the first Clean Development Mechanism (CDM) Project in Malaysia which is encouraged by the government to invest R&D efforts and to study the feasibility of applying the model throughout the country's industrial sector. With the investment cost of 38 million MYR, the biomass power plant is successful reduced 377,902 t of CO_2 emission by end of 2012 (CDM, 2006).

Most of the current application of biomass to power are focused in utilisation of EFB due to its high HHV content and abundant of feedstock from palm oil mill. Up to date, there is no utilisation of forest biomass or oil palm plantation biomass for power generation in Malaysia. Nevertheless, the forest and oil palm plantation biomass are proved to have similar HHV content as the EFB (20 MJ/kg compared to 17 MJ/kg) and thus could be a potential source of feedstock for power generation.

This study presents the economic potential using 2,000 t/d forest and oil palm plantation biomass (OPF and OPT) as the feedstock for power generation with main focus on electricity production. The proposed technology is a 27 MW capacity direct combustion system with a 76 % efficiency comprising of a pre-treatment drying system, fluidised bed boilers for conversion of biomass to heat and steam, and generation of electricity through extraction-condensing turbine. The biomass feedstock with an assumed calorific value of 15.82 MJ/kg with 16 % moisture content (dry basis) (Fiseha et al., 2012). The direct combustion technology has a 30 years plant life with investment cost of 900 $/kW and 1,050 $/kW for boiler and turbine respectively. The costing information was obtained through personal interview with a local biomass-to-power industry stakeholder while the financing data are adopted from NREL report (Humbird et al., 2012).

Using the net present value (NPV) economic analysis, the correlation between the minimum electricity production cost and the equity financing is presented in Figure 2 Minimum electricity product cost ranged from 0.23 $/kWh to 0.19 $/kWh with variations of equity financing share of 30 % to 70 %. The minimum product cost is consider high even with the equity financing adoption as compared to the current feed-it-tariff (FiT) incentive of 0.10 $/kWh.

As can be seen in Figure 2, there are only a marginal reduction in the minimum electricity price (ranged from 0.24 $/kWh to 0.19 $/kWh) for different capacities (2,000 t/d, 1,000 t/d, and 500 t/d) due to economy-of scale capacity increment with high fixed investment cost (approximately 3,000 $/kW). It was found that the low FiT scheme renders the biomass-to-power to be less competitive at the current power industry market.

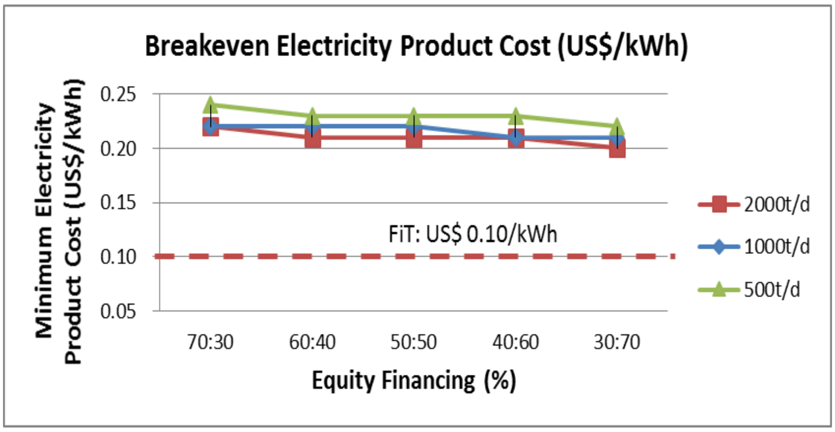

Figure 2: *Breakeven of electricity selling price for biomass-to-power in Malaysian context.*

3.2 Biomass to Bioethanol Generation

Maximum valorization of biomass can be achieved through its conversion to biofuels such as ethanol. The conversion of lignocellulosic biomass to biofuels and biochemical follow similar routes consisting of pre-treatment, hydrolysis, microbial conversion followed by purification. While the process of conversion to biofuels in the form of bioethanol has been commercially established, the processes for conversion to other biofuels such as butanol and biochemical are not commercially available at the present time. There are a number of processes in the pilot or pre-commercialisation stage all over the world (Becker et.al., 2015) and it is predicted that commercialisation of a few biochemical processes will happen in the next 5 years. Within this scenario, this report will focus on describing the process involved in the production of bioethanol as well as its economic evaluation in the Malaysian context to serve as a first estimate for a more rigorous evaluation.

The case study for biomass to bioethanol presents the economic potential using 2,000 t/d biomass as the feedstock. The proposed technology is enzymatic hydrolysis followed by fermentation with the cellulosics content in biomass of 70 % and conversion yield of the cellulosics to C5 and C6 sugar of 95 %. The fermentation process is using high substrate tolerant recombinant yeast capable of converting 30 % fermentable C5 and C6 sugars to 15 % ethanol. The technology has a 30 years plant life with the total capacity cost of $ 1,094,065,600.00. The major variable cost is assumed to be the enzyme cost of about 0.6 $/gal of ethanol.

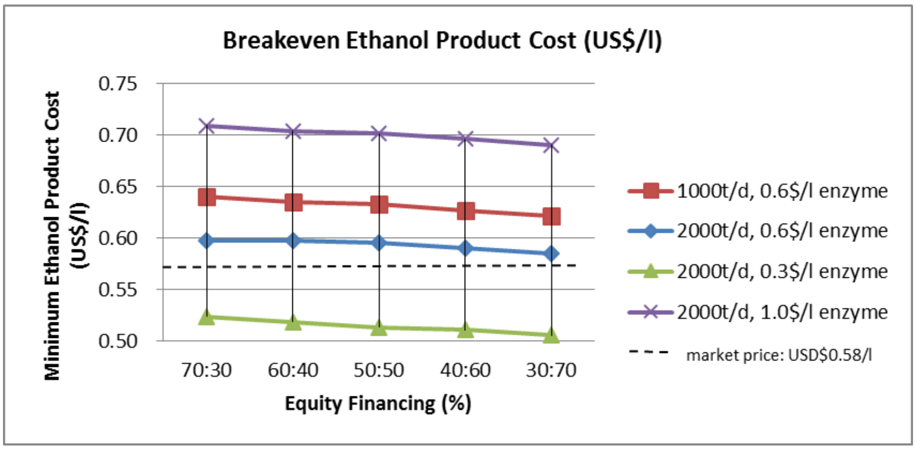

Figure 3: Breakeven of ethanol selling price for biomass-to-ethanol in Malaysian context.

Table 3: Ethanol production cost ($/L) reduction by improving the debt: equity ratio or interest rate

Debt:Equity ratio	Interest Rate		
	8 %	5 %	3 %
95:5	0.77	0.61	0.52
70:30	0.73	0.60	0.53
60:40	0.71 (0.57[a])	0.60	0.53
50:50	0.69	0.60	0.54
40:60	0.67	0.59 (0.52[b])	0.54

[a]US NREL (2011) [b]Adapted from US NREL analysis

Using the net present value (NPV) economic analysis, the correlation between the ethanol production cost and equity financing is presented in Figure 3. For a production capacity of 2,000 t/d, the production cost ranged from 0.64 $/L to 0.62 $/L with the movement of equity financing share from 30 % to 70 % which is higher than the current market ethanol price of 0.58 $/L.

Figure 3 also shows the variation of ethanol production cost at different capacities and with variation in enzyme costs. The plot demonstrates that economic viability from lower ethanol production cost can be achieved at favourable equity financing ratios, higher capacities (due to economy of scale) and lower enzyme costs.

Table 3 presents the potential of ethanol production cost reduction by improving the debt: equity (D:E) ratio or interest rate. It is shown that at the interest rate of 3 %, the ethanol production cost could be reduced significantly and make it competitive to current market value.

4. Conclusion

The two case studies presented in this study reveal the economic potential of conversion of biomass-to-power and ethanol in current market. For biomass-to-power, the current FiTscheme is relatively lower than the electricity production cost, rendering the biomass-to-power option less attrative to investors. The rate of FiT scheme in Malaysia was established in year 2011, and is considered not up-to-date on current renewable resources market as various RE resources have been more economically competitative in recent years. In order to promote the utilisation of biomass to power, the current Fit should be reviewed and revised.

The case study of biomass to ethanol, on the other hand, demonstrates a favourable scenario to the investors. As discussed, with a financial interest rate of 3 %, ethanol production is economically competitive in the current market. Nevertheless, the current interest rate stands at the rate of 5 % - 8 % and with high cost of enzyme in Malaysia, there needs to be some policy and technology intervention to enablea sustainable bioethanol industry in Malaysia. The problem is further compounded when the investments is undertaken through acquisition of bank loans thus increasing the operational cost from interest payment. It is proposed that there is a significant funding involvement from the government converted to equity to minimise the interest charges from massive loans. The equity-loan ratio needs to be optimised to maximise margins on sale of ethanol from a financial evaluation.

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