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Current state and environmental impact assessment for utilizing oil palm empty fruit bunches for fuel, fiber and fertilizer – A case study of Malaysia

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ABSTRACT

This paper describes the trend of utilizing oil palm residue, i.e. the empty fruit bunches (EFB) left after extraction of the palm oil, using a case study of Malaysia, which is one of the world's major palm oil producers, and discusses the environmental performance of recycling technologies being developed in Malaysia for fuel, fiber, and fertilizer. Seven technologies are analyzed: ethanol production, methane recovery, briquette production, biofuel for combined heat and power (CHP) plants, composting, medium density fiberboard (MDF) production, and pulp and paper production. The life cycle assessment (LCA) method is used to discuss the environmental impacts of these technologies for adding value to this biomass. Sensitivity analyses are conducted to determine the land use effects for the various technologies utilizing EFB and to estimate the energy generation potential of raw EFB in CHP plants and methane production. Among the technologies for energy production, CHP plants have the best performance if the electricity generated is connected to the national grid, with superior benefits in the majority of impact categories compared to briquette, methane, and ethanol production. Overall, we find that methane recovery and composting are more environmentally friendly than other technologies, as measured by reduction of greenhouse gas emissions. Pulp and paper, and MDF production are favorable technologies for land use impacts; however, they have intense primary energy requirements, chemical use in the processes, and emissions from their waste treatment systems. Our results provide information for decision makers when planning for sustainable use of oil palm biomass.

1. Introduction

Malaysia is one of the top producers of palm oil in the world, with a total area of 50,000 km^2 of oil palm plantations. A total of 423 palm oil mills are operating in Malaysia. In 2011, a total of about 92.9 million tonnes of fresh fruit bunches (FFB) were harvested and processed in the palm oil mills, resulting in the generation of about 44 million tonnes of solid oil palm residues and 62 million tonnes of palm oil mill effluent during the palm oil extraction. The solid oil palm residue is a biomass consisting of, by wet weight, 23.8 million tonnes (54%) of empty fruit bunch (EFB), 13.2 million tonnes (30%) of shell, and 7.9 million tonnes (18%) of fiber [1].

The palm oil industry accounts for the largest biomass production in Malaysia, and since the 1960s, all palm oil mills have depended on their own biomass for fuel, using mainly the shells and fibers. However, the empty fruit bunches have not

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been optimally used, because they are wet, bulky, and voluminous, which are unfavorable properties for transportation and handling; instead, they have been left by the millers to rot at the palm mill and plantation. Palm oil mill effluent (POME) also represents the largest potential for biomass energy utilization in the country, but this resource is readily available and in need of an efficient and effective means of utilization [2]. Studies have reported that only about 30% of palm oil mills in Malaysia are involved in recycling activities for EFB and POME [3]. In order to improve the environmental performance of palm oil production, the industry must start being concerned with using all resources from the oil palm in an optimal way, while at the same time minimizing the environmental impact of the recycling systems in or outside of the mill.

Several different technologies have been developed and are now available in the market for effective use of oil palm residue, especially EFB as main feedstock. However, most of the palm oil millers do not have a directive for choosing which technology to invest in to solve the issue of EFB disposal [3]; therefore, they continue to practice the old disposal method. This situation also creates difficulties for third party investors in recycling technologies who need to acquire EFB for their feedstock. Indeed, palm oil millers must become acquainted with many recycling technology options and learn how best to utilize the EFB, for fuel, fiber or fertilizer. They must weigh the benefits and drawbacks of the products, by-products or energy that are generated. Policy makers should provide information about the technologies and establish guidelines to help millers reduce the environmental impact and boost the growth of the recycling industry, in order to bring optimal benefits to the millers and the nation.

A few studies have been carried out to evaluate the environmental impacts of palm oil production, which include conventional recycling methods in palm oil mills [4–6]. For this study, the development of recycling technology options available in the market for effective use of EFB, as well as policy initiatives promoting these new technologies have been reviewed. The aim was to develop a basis data set to evaluate the environmental impact of these technologies using the life cycle assessment (LCA) method. This study will show how LCA can be useful for the evaluation of technologies used for processing the EFB and the conditions under which some EFB utilization chains can be made environmentally sustainable, using the results from studies conducted in the recent past. Sensitivity analyses were conducted to determine the land use effect of every technology and to compare the energy generation potential for the raw EFB use in CHP plants with methane recovery. A life cycle based comparison of different technologies for utilizing EFB is useful for making decisions for recycling technology options and for providing information about effective and economical combinations of different conversion systems. The results provide a benchmark for continuing improvement of environmental performance and can aid in the creation of a road map for sustainable utilization of EFB.

2. Methods

In this study, seven different technologies are considered – four using EFB as biofuel and three using EFB as material: 1) Ethanol production, 2) Methane recovery, 3) Briquette production, 4) CHP plant, 5) Composting, 6) MDF production, 7) Pulp and paper production. The life cycle assessment approach was used to discuss the energy consumption and the overall environmental impact of different technologies for utilizing EFB. The analysis considered the pre-treatment, processes involved in every technology, and final disposal of the wastes that remain after the process. The benefits of the various environmental impacts are also evaluated by considering the allocation of avoided products within the system boundaries for each technology.

3. Current status of recycling technology options

To make use of EFB biomass, many new technologies have been developed at local research institutes such as the Palm Oil Research Institute of Malaysia (PORIM), Malaysian Palm Oil Board (MPOB), and Forest Research Institute Malaysia (FRIM), in collaboration with local universities. These recycling technologies described below convert EFB to biofuel and value-added products.

3.1. *Ethanol production*

In 2006, the Malaysian National Biofuel Policy was launched by the government to reduce fuel consumption, especially in the transportation and industry sectors, by promoting palm oil as the main commodity for biofuel production, with the added benefit of stabilizing palm oil prices. However, the high price of crude palm oil, controversy over palm oil for food versus fuel, and the issue of sustainable biofuel production have discouraged utilization of palm oil for biofuel production [7]. EFB is regarded as an excellent feedstock for the production of biofuels due to its abundant supply, year-round availability, and because unlike palm oil, it is not used as food and feed. The process of converting EFB to ethanol is more complex than current ethanol production from corn or sugarcane, because the complex cellulose–hemicellulose–lignin structure needs to be broken up before fermentation can begin. Consequently the technology is not yet used on a commercial scale. Researchers are finding the most effective and low-cost enzymes for the pre-treatment and organisms for the fermentation process.

A test done by BioCentrum at Denmark's Technical University estimated that 1 tonne dry EFB is able to produce 0.39 m^3 of ethanol using a new process (wet explosion) for pre-treatment [8]. Other techniques, however, have proven to be less efficient. Piarpuzán et al. [9] demonstrated a method of ethanol production from EFB using alkaline pre-treatment and enzymatic hydrolysis approach, which yielded ethanol at only 0.067 $m^3\ t^{-1}$ of dry EFB. Millati et al. [10] also using dilute sulphuric acid pre-treatment, achieved a yield of 0.112 $m^3\ t^{-1}$ of dry EFB. Yano et al. [11] developed new yeast strains, and utilized milling pre-treatment, with enzyme hydrolysis, resulting ethanol yield 0.13 $m^3\ t^{-1}$ of dry EFB.

On 28, Dec 2010, Sime Darby Plantation Sdn. Bhd. began collaborating with Mitsui Engineering and Ship building Co. Ltd. (MES) of Japan to construct and operate the first bio-ethanol demonstration plant which will convert oil palm EFB