# Routing Model of Oil Palm Fibre Waste toward Gas Fuel Production Supply Chain Management: Malaysia Industry

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***Abstract.*** **Green energy is becoming an important aspect for developed countries in the world toward energy security by reducing dependence on fuel import and enhancing better life quality by living in sustainable healthy environment. Issues regarding renewable energy production are source sustainability and reliability to ensure continuous production. Palm oil operation produces 80% varies type of waste and 20% oil palm products. Different range of physical and chemical of palm oil waste properties request different particular treatment and conversion energy method to optimize the desired bio product. Aim of this paper is to suggest the best *Routing Model of Oil Palm Fibre Waste toward Gas Fuel Production Supply Chain Management* based on evaluation of current Malaysia's palm oil industry, practices in palm oil waste treatment and available energy conversation technologies. The framework is based on palm oil mill operation to utilise annually solid waste generated as source for stable annual biogas electricity production for grid. This paper highlight framework for the prospective researchers as well as practitioners to do further research to optimizes utilisation of palm oil waste for electricity production.**

***Keywords*** -- *Green supply chain, Natural-Resource, Waste treatment, Green electricity, Biogas*

## 1. INTRODUCTION

Renewable energy development is not for replacing fossil fuel in short time period, but to reduce environmental problem and seek of energy security purpose. With the recent growth in oil, gas and coal consumption for electricity production, Malaysia has experience high growth in green house emission level due to carbon dioxide ($CO_2$) gas emitted [3, 4]. Malaysia government decided to enhance the coal import volume and renewable energy development based on solar, biomass and biogas source to support demand acceleration [36].

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Renewable energy project that have achieved commercial operation from year 2012 - 2014 in Malaysia show that biomasses source give the highest electricity energy generation (GWh) through incineration approach [43].Research division of Tenaga Nasional Berhad is working on gasification technology based of coal to produce syngas for available gas turbine [4]. Coal releases high quantity of $CO_2$ [3] compared to methane and syngas gas fuel source. Biogas may be produce from biomass, manure, garbage and food waste. The problem facing with biomass energy production is ensuring supply sustainability for sustainable power generation. This is due to fluctuation in supply source, weak handling and low technology efficiency [1, 2, 20]. Transition of non-renewable energy toward domination of renewable energy sources involved other aspect such as supply chain management, social acceptance and government policy [8].

Malaysia electricity source are gas (53.8%), coal (35.3%), hydro (10.3%), distillate (0.6%) and Medium Fuel Oil (MFO) (0.04%) that are use to full fill the demand for electricity in peninsular Malaysia that the peak demand is 16,901 MW in 2016 [4]. Malaysia government had established Sustainable Energy Development Authority (SEDA) and introduces fit in tariff (FiT) system to enhance private sector involvement in renewable energy industry development [5]. Currently, biomass power sector in Malaysia is facing barriers regarding the movement of energy through a place, time and existing energy infrastructures due to lack of knowledge on technologies and effective supply chain management [20] plus with varies properties of biomasses that contribute to several chemical and physical data that need different production approach [10].

The final products of biomass process will differ depend on biomass type, conversion technology and source's environment [12]. Malaysia country starts producing biogas in parallel with producing biodiesel on year 2013 with production capability of 6,000 bbl. /day, and a significant quantity of ethanol produce from laboratories work by local researchers from universities [2, 23]. Malaysia currently marketed significant amount of oil palm biomass waste for biodiesel production to Singapore and Europe [1, 5].

## 2. Methods and Techniques: Literatures Analysis

### 2.1 Biogas Production

The complexity in implementing renewable energy can be disintegrate with further research on converting energy process, technology, supply chain and effective management [4, 37, 41]. Malaysia government has identified four major renewable electricity power resources that practicable for Malaysia usage that are hydro, wind, solar, and biomass that included biogas and municipal solid waste. [5]. Currently, Malaysia doesn't produce biogas but then capture from landfill [43]. Biogases refer to mixture of various type of gas and are name based on the major gas composition in the mixture such as biomethane that have methane composition range from 60% to 85%. Other gases present are hydrogen sulphide and carbon dioxide besides moisture and siloxanes mix up. Biogas can be produce via organic molecule breakdown by specific anaerobic bacteria in absence of oxygen.

Raw materials used to produce biogas are plant, crop, agriculture waste, food waste, municipal solid waste and manure. Several issues rise on food shortage if plantation use for producing energy. These issue make researcher changes the direction toward manipulate waste toward producing biogas such as waste from food industry, manure, agriculture and sewage [19]. Biogas has to be purified until methane composition more than 90% for vehicle and biomethane. Biomethane can be produce by removing certain unneeded gas such as carbon dioxide and impurities such as Sulphur and moisture that benefited for environment and cost saving compare to diesel usage [29, 32]. Biogas can be storage as compressed natural gas in liquid form used for vehicle as practice by United Kingdom with 17% of country usage [39].

Variation of biogas composition is contribute by its origin either landfill or chemical process plant. Standard landfill gas will has estimate 50% methane concentration, advance waste water treatment may produce around 55% - 75% methane concentration while anaerobic digestion plant can produce around 65% - 85%. In situ gas purification technique is able to enhance methane concentration up to 95%. [6]. Significant vary in biogas production can also occur based on operating parameter and physical condition of loading feedstock and feedstock's heat value. Higher heat value will result in higher methane composition produce [45]

### 2.2 Biomass to Energy Conversion Technique

Difference energy conversion technique and parameter applied will produce different products type and energy volume. Maximizing energy produce, continuous supply sustainability, technology available, initial cost and operating cost must be consider in deciding type of energy conversion technique to be used [29,32,35].

Table 1 describe on available conversion energy technology, briquette and palletize. Conversion energy technologies are divided into two main categories that are thermo chemical and bio chemical process.

**Table 1**. Available conversion energy technology, briquette and palletizing

| Ref. | Technique | Description |
|---|---|---|
| Thermo Chemical | | |
| [40] | Direct Fired | Involve specific applied technologies that are stoker boilers, fluidized bed boilers and co-firing. Current dominated plant of biomass to produce electricity via steam. |
| [29] [44] | Co-firing | Burning of mixture of two type of fuel source such as combination of biomass and coal or combination of biomass and natural gas. Common co-firing is natural gas and biogas, pallet biomass and coal. |
| [38] [45] | Gasification | Syngas (hydrogen) as sale gas that can be cleaned, filtered and burn in a gas turbine either using combine cycle or simple system. Syngas can be fired in reciprocating engines, micro turbines, stirling engines, or fuel cells. Gasification on biomass is being use hugely for paper industry and pulp. The practitioners improvise chemical recovery toward producing higher process steam and electricity efficiencies with less capital cost than conventional technologies. |
| [46] | Parolysis | Distillation permanent with slow chemical reaction that occur in low temperature to decompose biomass without oxygen enclose to convert biomass into bio oil, biogas and solid residue. |
| Bio Chemical | | |
| [20] [30] | Anaerobic Digestion (AD) | Naturally organic process that results in the breakdown of organic matter by naturally occurring bacteria in an environment with absence of oxygen. Produces methane gas, $CO_2$ and residual digestate. Methane gas is/are used to fuel boilers for heat and/or spin gas turbine for electricity. AD process can be used to treat waste and reduces green-house gases. AD plant can take place at a location local to where waste is produce which reduce the need for transportation. Retention time is 10-30 days. |

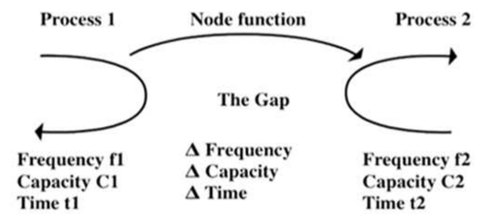
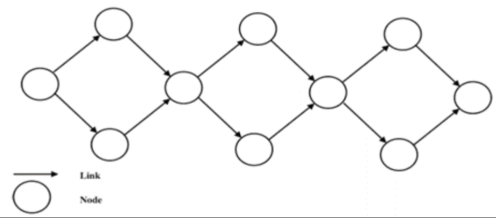
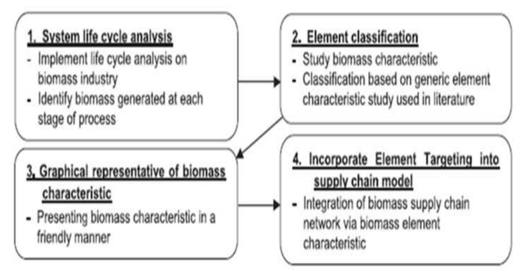
| | | |
|---|---|---|
| [28] | Fermenta-tion | Involve breakdown of sugar substrate into liquid alcohol form using yeast. Specific type of catalyst use to break down the biomass large organic molecules. Biomasses contain starch that produce in plant photosynthesis process. The starch will be converted into sugar substance within the fermentation process. Then enzyme will react to decompose cellulose contain in biomasses fibers and produce ethanol. Main product desire is ethanol, by product generate are non-fermented sugar, carbon dioxide, yeast cells and non-fermented biomass |
| Briquettes and Palletizing | | |
| [31] [34] [42] [47] | Briquettes | Biomass briquetted can be used together with coal or natural gas as fuel. Biomass briquette able to reduce cost for storage and logistic by its uniform shape and dense, can be burn longer time and may contains mix of several type of biomass. Difference type of biomass can be mix to produce briquette such as of glycerin and biomass based on mixture specification. Varies based on biomass briquette density and size. |
| [31] [34] [47] | Palletizing | Commonly for biomass's wood based material only. |

## 2.3 Biomass Supply Chain Management

Lack of knowledge in biomass potential, handling, logistics and technology lead toward less effort taken to discover biogas from biomass fuel potential plus slight confident and support from government [11]. Malaysia has been boon with the equatorial monsoon and fertile soil which make this country suitable for many types of plantation such as rubber, palm oil, cocoa, coconut, durian, rambutan and mango. As an example, Malaysia palm oil industry spans roughly 5.23 million hectares of fields and generates $ 255 million per year [6, 7].

Based on supply chain perspective, decisions have to be put together regarding on type of feedstock, processing plant, distribution system and demand profile [11]. To achieve sustainable gas supply, several factors involve are diversify gas sources, supply quantity, storage capacity, transportation, production, demand, infrastructure, economic, technical risks, environmental, regulation and political [15, 21, 22, 26]. Complexity to produce biomass energy arise huge of research undertake in many study field such as computer simulation [8,14,17,25], mathematical algorithm [11], technology management [13,26], laboratory experiment [5] and supply chain management [24,27]. Theoretical models and framework are used as analytical tool to develop Routing Model of Oil Palm Fibre Waste toward Gas Fuel Production Supply Chain Management are show in table 2 below:

**Table 2**. Theoretical model/framework

<table>
<tr><th>Ref.</th><th>Theoretical Model/Framework</th></tr>
<tr><td>[9]</td><td>The function of the terminal

</td></tr>
<tr><td>[15]</td><td>A model of transportation

</td></tr>
<tr><td>[12]</td><td>BELCA Framework

</td></tr>
</table>

## 3. Result and Discussion

Innovation, operation and strategy are essential in technology management including supply chain structure. There are three types of flow considered in the supply chains management that is material flow, financial flow and information flow. This suggested Routing Model can be used to identify those aspects. [26]. This research is limited to several dimensions that are focusing only on the palm oil fiber waste physical flow that is material flow starting from waste produce in mill until electricity grid supply. Focus give on innovation of operation process to ensure green electricity supply continuity.

Figure 1 below is the suggested Routing Model of Oil Palm Fiber Waste toward Gas Fuel Production Supply Chain Management that purpose as a conceptual structure which intends to serve as basic guide for conducting research activities toward determine objectives and outcome for palm oil mill case study to treat fiber waste for gas fuel production. A node refers to a geographical position of activities involved within the supply chain system from supply origin until meeting demand [15]. The nodes could be supply sources, a location of storage, transshipment or processing of goods and termination point.

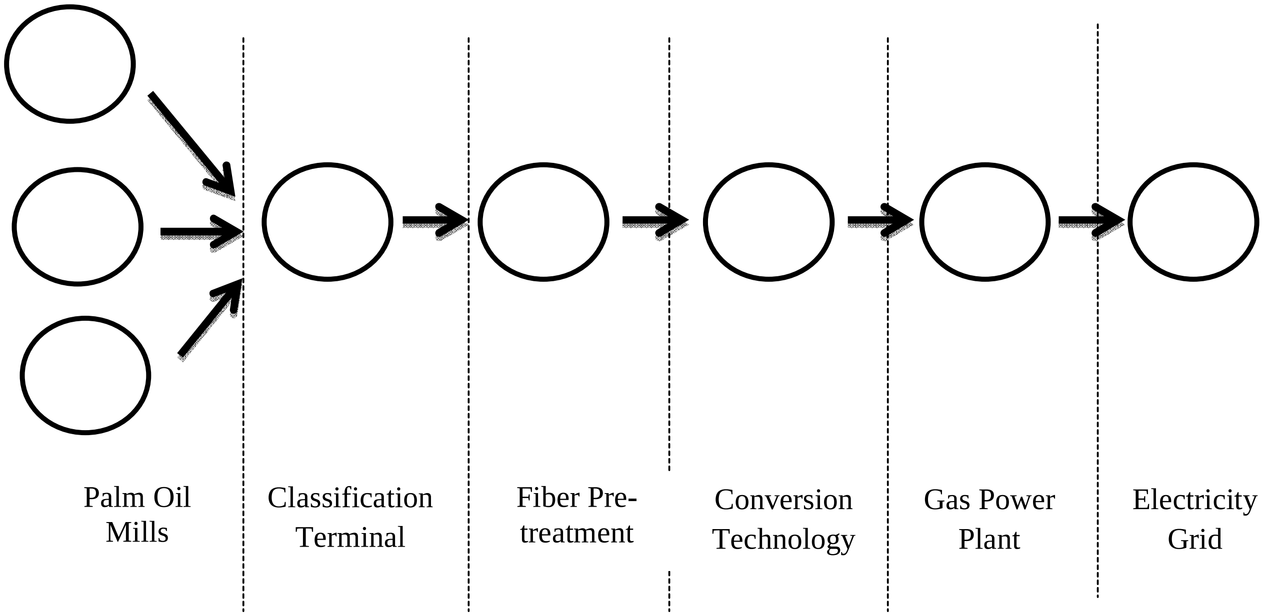



**Figure 1.** Routing Model of Oil Palm Fibre Waste toward Gas Fuel Production Supply Chain Management

Ref. [15] stated that by appointed nodes, a system must be able to bridge gaps between types of transportation. The gaps of product's physical flow will be closer in term of frequency, capacity and time consuming. Transportation defines a network of links and nodes. Links which appointed by arrow used to connect nodes. Vehicles, vessels and pipeline infrastructure either through water, air or land are used for the physical transfer [9]. Referring to literature review, palm oil waste biomasses able to produce two type of gas fuel depend on type of conversion technology. BELCA Model proposed that biomass supply chain network will be vary depend on element of biomass. . This paper is suggesting a basic routing supply chain model for palm oil fiber waste for gas fuel electricity production. The propose routing model can be further elaborates based on palm oil mill locations, type of biogas desired, type of conversion technology, specific type of fiber's source, feedstock volume, and feedstock phase either solid, liquid or gas.

Different type of transportation needed for logistics between each node due to product phase that is either solid, gas or energy. Palm Oil mills ($N_1$) has varies amount of daily waste produce based on volume of FFB received, manufacturing capacity and oil demand. Classification Terminal ($N_2$) will classify waste based on type for fiber waste collected to ensure the right feedstock. Wastes are classified to Palm Oil Mill Effluent (POME) and Palm Oil Solid Waste. POME is in semisolid phase while solid waste either in wood or fiber. Fiber Pretreatment ($N_3$) section is use to prepare feedstock load for Conversion Technology ($N_4$). The feedstock prepared based on operating parameter of type of conversion technology used.

Fiber Pretreatment ($N_3$) may involve several process depend on type of Conversion Technology ($N_4$) as discuss as discuss in Section2.2. As example, if Conversion Technology ($N_4$) is direct fired, the palm oil solid biomass use will be dried up to meet the desired moisture content. Otherwise, the solid waste also can be store either in briquette or pallet form. Fuel source produce from Conversion Technology ($N_4$) will be transfer to Gas Power Plant ($N_5$) either via vessel or pipeline based on material phase. Electricity produce at Gas Power Plant ($N_5$) will be wired transfer to Grid ($N_6$) for domestic users.

## 4 Conclusion

Contributing to the conceptualizations of Routing Model of Palm Oil Fibre Waste toward Gas Fuel Production Supply Chain Management can be a useful basis to improve current practise, explaining new methods, and guiding towards the emerging integrated of available technology for fully utilize energy potential from palm oil waste biomass in Malaysia focussing in supply chain management context. Discussing the potential and benefit of biogas usage in electricity production, in parallel with type of conversion technology available to process palm oil solid waste for beneficial product, in hope will leads to further works, giving inspirations and insights to other renewable energy researchers to produce efficient biomass supply chain management, enhance energy security, energy sustainability, improving healthy environment and economic sustain in future.

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