Development of Oil Plam Fiber Waste Inventory System for Optimal Electricity Grid Supply: Biomass Briquette

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Abstract— **Green energy is becoming a consequential aspect for developed countries in the world toward energy security by reducing dependence on fuel import and enhancing better life quality by living in a sustainable salubrious environment. Issues regarding of renewable energy engenderment in context of supply chain management is the source supply reliability to ascertain sustainable volume for optimal energy engenderment. Supplier risk may involve material delay, operational conduct, storage system, raw material quality and distribution. Different range of physical and chemical of biomass properties request different particular operation strategies to optimize the engenderment. The aim of this paper is to provide a constructive conceptual framework for integrating oil palm fibre waste inventory management into a portfolio of biogas supply chain for optimal electricity engenderment. Observation on industrial practise and deeper study on cognate literature review had been conducted. This study represent two findings that are "Bio-briquette Usage in Value Chain of Oil Palm Fibre Waste - Electricity Grid Supply" and "Closed Loop Supply Chains (CLCS) of Oil Palm Fibre Waste for Electricity Production by Producing Bio Methane Fuel".**

***Keywords*—** *Inventory management, biomass briquette, oil palm fibre waste, biogas, value chain*

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 greenhouse gas emissions and pollutants in 2040 can be reduced by up to 80 %, compared to emissions of 2020, without any adverse effect on vehicle demand nor the economy [1]. Malaysia government decided to enhance the coal import volume and renewable energy development based on solar, biomass and biogas source to support demand acceleration [2]. Renewable energy project that have achieved commercial operation from year 2012 - 2014 in Malaysia for electricity energy generation (GWh) is through incineration conversion technique [3]. Research division of Tenaga Nasional Berhad is working on gasification technology based on coal to produce syngas for existing gas turbine [4]. Coal releases high quantity of CO2 [5], compared to methane and syngas fuel. Biogas may be produce from biomass, manure, garbage, and food waste. The problem facing with biomass energy production is ensuring supply sustainability for sustainable electricity generation. This is due to fluctuation in supply source, weak handling and low technology efficiency [6]. Transition of non-renewable energy toward renewable energy usage involved several aspects such as supply chain management, social acceptance and government policy [7]. Malaysia electricity source are natural gas (53.8%), coal (35.3%), hydro (10.3%), distillate (0.6%) and Medium Fuel Oil (MFO) (0.04%) that used to full fill the demand for electricity in Peninsular Malaysia. Current the peak demand is 17, 175 MW on March 2016. This broke the previous record the peak demand of 16,901 MW registered on June 6, 2014 [2]. 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 [8]. The complexity in implementing renewable energy can be disintegrate with further research on converting

International Journal of Supply Chain Management
IJSCM, ISSN: 2050-7399 (Online), 2051-3771 (Print)

energy process, technology, supply chain and effective management [9].

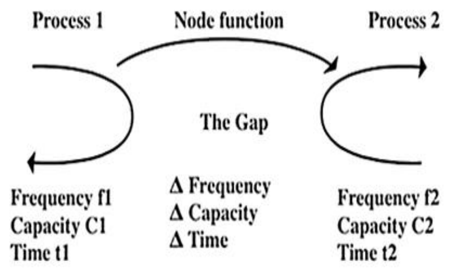
2. Methods and Techniques: Literature Analysis

2.1. Biomass Supply Chain Management

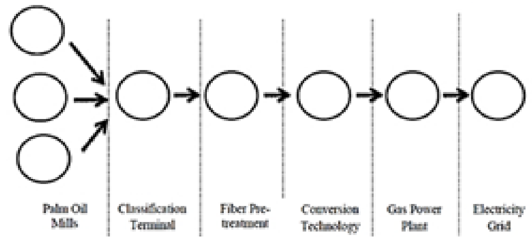
Lack of knowledge in biomass potential, handling, logistics and technology lead toward less effort taken to discover biogas fuel from biomass potential plus slight confident and support from government [10]. Malaysia has been boon with the equatorial monsoon and fertile soil which make this country suitable 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 [11,12]. Currently, biomass power sector in Malaysia is facing barriers regarding the movement of energy through a place, time and existing energy infrastructures due to insufficient information on technologies and effective supply chain management [13] plus with varies properties of biomasses that contribute to several chemical and physical data that need different production approach [14].

Biofuel produced is depend on biomass type, conversion technology and operating parameter [15]. Based on supply chain perspective, decisions have to be put together regarding on various factor such as harvesting, transportation, storage, preprocessing, type of feedstock, processing plant, distribution system and demand profile [16]. 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 [13], [17-20].Complexity to produce biomass energy arise huge of research undertake in many study field such as computer simulation [21], mathematical algorithm [10], technology management [22], laboratory experiment [23] and supply chain management [24]. Theoretical models and framework are used as analytical tool to develop “Framework of Waste Biomass Recycle for Optimal Sustainable Electricity Supply: Biogas Fuel” are show in table 1 below:

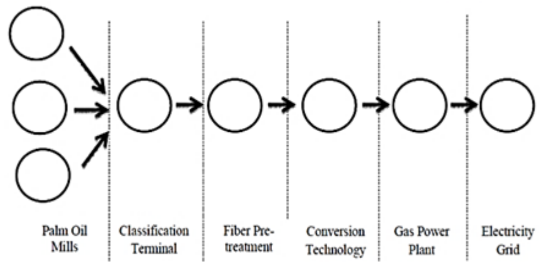
Table 1.Theoretical model/framework



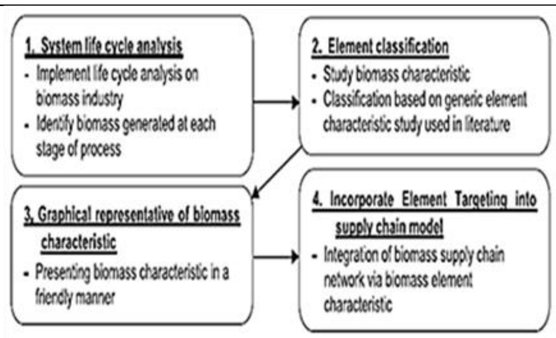
The function of the terminal [39]



Sustainable Supply Chain Management [5]



Routing Model of Oil Palm Fibre Waste toward Gas Fuel Production Supply Chain Management [50]



BELCA Framework [11]

2.2. Waste Biomass

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 [3]. At present, Malaysia capture biogas from landfill [8]. 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 [25]. Variation of biogas composition is contribute by its origin either landfill, pond or process plant. Biogases refer to mixture of various type of gas and are name based on the major gas composition in the mixture such as bio methane 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 [16]. 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% [11]. Significant vary in biogas production can also occur based on plant operating parameter, physical condition of loading biomass feedstock and feedstock's heat value. Higher heat value will result in higher methane composition produce [26]. Different type of biomass feedstock will impact the capital and operational cost of a conversion energy plant.

Figure 1(a,b) shows different percentage allocations for capital expenditure depend on the type of biomass feedstock to produce bio methane gas. Another graph shows that percentage cost allocation for feedstock is higher compared to other cot of variable inputs. Fully waste usage as feedstock able to reduce 60-70% of operational cost [27].

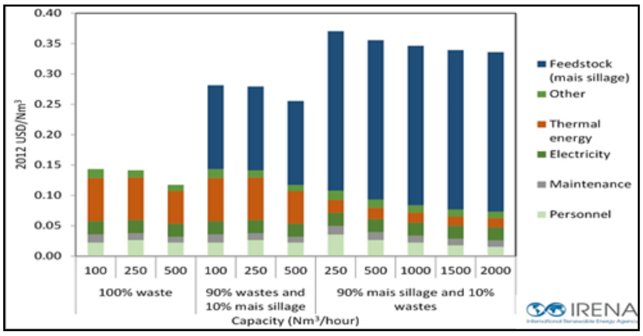


Figure 1a. Capital Costs per Unit Capacity for AD Systems by Plant Size and Feedstock

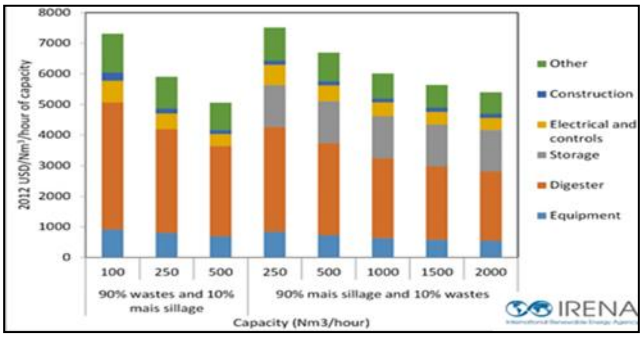


Figure 1b. Operating Costs for AD Biogas by Feeding and Size

2.3. Biomass to Energy Conversion Technique

Application difference type of energy conversion technique will produce different type of products. Table 2 describe on existing conversion energy technology.

Table 2. Conversion energy technology

Type	Description
Thermo Chemical	
Gasificat-ion	Produce 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 [28].
Parolysis	Distillation permanent with slow chemical reaction that occur in low temperature to decompose biomass without O_2 enclose to convert biomass into bio oil, biogas and solid residue [29].
Bio Chemical	
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 used to fuel boilers for heat and/or spin gas turbine for

	electricity. Retention time is 10-30 days [6]
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 [4]

2.4. Type of Power Plant

90% of Malaysia's thermal electricity production depends on petrol oil, diesel oil, and natural gas. TNB uses the conventional steam turbine that fired mainly by natural gas, coal, and diesel. There is two type of plant that is open cycle gas turbine (OCGT) generator and combined cycle turbine (CCT) generator [2]. Malaysia has been rewarded with various types of potential renewable energy sources that use to produce electricity such as wind, biomass and solar. One of the initiative taken by TNB was by established handbook title "TNB Technical Guidebook on Grid-interconnection of Photovoltaic Power Generation System to LV and MV Networks" to ensure efficient renewable energy management on solar [4].

Implementing renewable energy is not an easy work, and it goes same with Malaysia. Various research, prototype and testing work on renewable energy in several locations able to figure out some issues on renewable energy use in Malaysia which can be upgrade by time. Such examples are wind turbine located in east of peninsular Malaysia show that some precaution has to make to prevent wind turbine from bad weather cause such as lightning struck. Besides, solar generators face with discontinuous hot weather conditions [30]. Initiative in energy storage needed to overcome the situation where it's cloudy, raining and short daytime. Hydro currently is the main renewable energy that contributes to renewable power in Malaysia, however, the volume produces still not sufficient to support the electricity need by country. A hybrid power usually consists of two or more renewable energy sources used together to provide increased system efficiency as well as greater balance in energy supply. The hybrid may involve renewable or non-renewable energy sources [31].

The main purpose of hybrid power stations is to reduce the dependency on non-renewable energy and urge implementing in greener energy source such as wind, solar, hydrogen, biomass and municipal solid waste. Malaysia is currently in the early stage to implement hybrid power stations to support current power production. TNB had implement Hybrid Solar System (HSS) Project for rural schools in Pahang state [30]. [32] found that the solar hybrid system installed able to full fill the school electricity need and makes access production for nearby houses. Another hybrid installation in Malaysia is at Pulau Perhentian, Terengganu that is wind turbine (200kW), solar power (100kW) and diesel generators (500kW) electricity production [9, 30].

2.5. Feedstock Inventory Management

A storage system can significantly influence the energy yield without changing important fuel quality parameters such as heating value and ash content. Dry matter losses of the biomass can be partially controlled by the conservation system use [33]. Densification is the process of turning biomass with high volume into a compact uniform low volume [34]. Some of the methods available for compaction of the residues are the piston press, screw press, roller press and palletizing machines. Densification mechanism of different biomasses involves an application of attractive forces between solid particles, interfacial forces, capillary pressure, adhesive and cohesive forces, mechanical interlocking behaviour and formation of solid bridges. The strength of the compactness depends upon material characteristics and process variables like pressure, temperature and use of binding materials [35].

2.5.1. Biomass Pelletizing

Biomass briquettes and pelletizing are bio-fuel that can substitute coal and charcoal. Pelletizing is commonly used for wood [33]. Pellet form in small shape. Large area of pellet make pallet could be totally auto-swollen in an hour [36]. Exploration on biomass pelletizing is conducted to examine the efficiency of energy production. [37] found that pelletizing pressure increased exponentially with the pellet length. The rate of increase was dependent on biomass species, temperature, moisture content and particle size. Increasing the temperature resulted in a decrease of the pelletizing pressure. Furthermore, thermal pre-treatment of the biomass need to identify the type of biomass used for pelletizing [37]. Biomass pellet can be used for different technologies, such as circulating fluidized bed (CFB) air and oxygen gasification, dual fluidized bed (DFB) steam gasification, and bio-synthetic natural gas (bio-SNG) production. Oxygen gasification using an iron ore pelletizing is apparently the best option as it provides a product gas with higher heating value. This proved that different source of biomass pellet is suitable for different type of conversion technique based on type of biomass processed. Increasing demands for biomass pellets also urge the investigation of alternative raw materials for pelletization [38].

Good quality pellets and satisfactory pelletizing should occur in the region where the friction decreases with die temperature. Therefore, the friction vs. die temperature curve measured for each biomass can be used as an indication of the right die temperature in large-scale pellet production [39].

2.5.2. Torrefaction

High torrefaction temperatures change the chemical properties of the biomass and compacting properties significantly. Torrefaction increases the friction in the press channel, material strength and density decrease with an increase in torrefaction temperature [40].

2.5.3. Biomass Briquetting

Briquette is form in a block. It took about 24 hour for briquettes be totally auto-swollen [36]. Current practise in developing country show biomass briquette been utilized more as heat for cooking while in develop country biomass briquette had been developed well to be used to heat industrial boiler, heat for residential and electricity production. Advantages of biomass briquette are reducing the cost for storage and logistic by its uniform shape and dense can burn longer time and may contain mix of several type of biomass [41]. The compact density of biomass increased with increasing pressure and moisture content. The relaxation properties of selected materials were affected by the set variables. Biomass materials had a higher stress relaxation speed with higher applied pressure and lower moisture content [11].

Excellent understanding of effective densification process is needed to produce durable briquette in order to avoid crack and enhance the heat value for useable, efficiency and sustainability energy purpose [42]. [43] stated that fibrous structure of proposed briquette relate toward combustion rate and heat release. Lower relaxed density and higher combustion rate will increase transportation cost for briquette. Densified biomass improved sugar concentration in diluted-NaOH pre-treatment. Briquette biomass performed less sugar conversion when using hydrothermal pre-treatment [43]. This demonstrates that biomass briquette is not effective use with all type of pre-treatment. Biomass-fuel producers have to identify the best ways for biomass briquette pre-treatment based on type of biomass feedstock such as anaerobic digestion technique [36-44]. Biomass briquette can include partially in coking blends for better cokes production [11].

3. Result and Discussion

3.1 Bio-briquette Usage for Sustainable Chain of Oil Palm Fibre Waste for Electricity Grid Supply

Bioenergy is a complex subject because of variety in energy sources and conversion technologies. Further laboratory experiments, supply chains study, operation & manufacturing efficiency, restructure of governance policy, economic analysis and social awareness need to be notify for sustainable bioenergy production. Figure 2 shows the proposed of Bioenergy Value Chain of Oil Palm Fibre Waste to produce electricity for grid supply. The chain starts from harvesting fresh fruit bunch then bring to palm oil mill for oil extraction. The fibre waste will be used as feed input to anaerobic digestion plant for bio methane production or biomass briquette mill to be processed and keep in storage. Bio methane gas will be used as fuel for gas turbine power station and produce electricity. Electricity produce is transmitted to grid power supply. Electricity form grid then will be distributed to consumer.

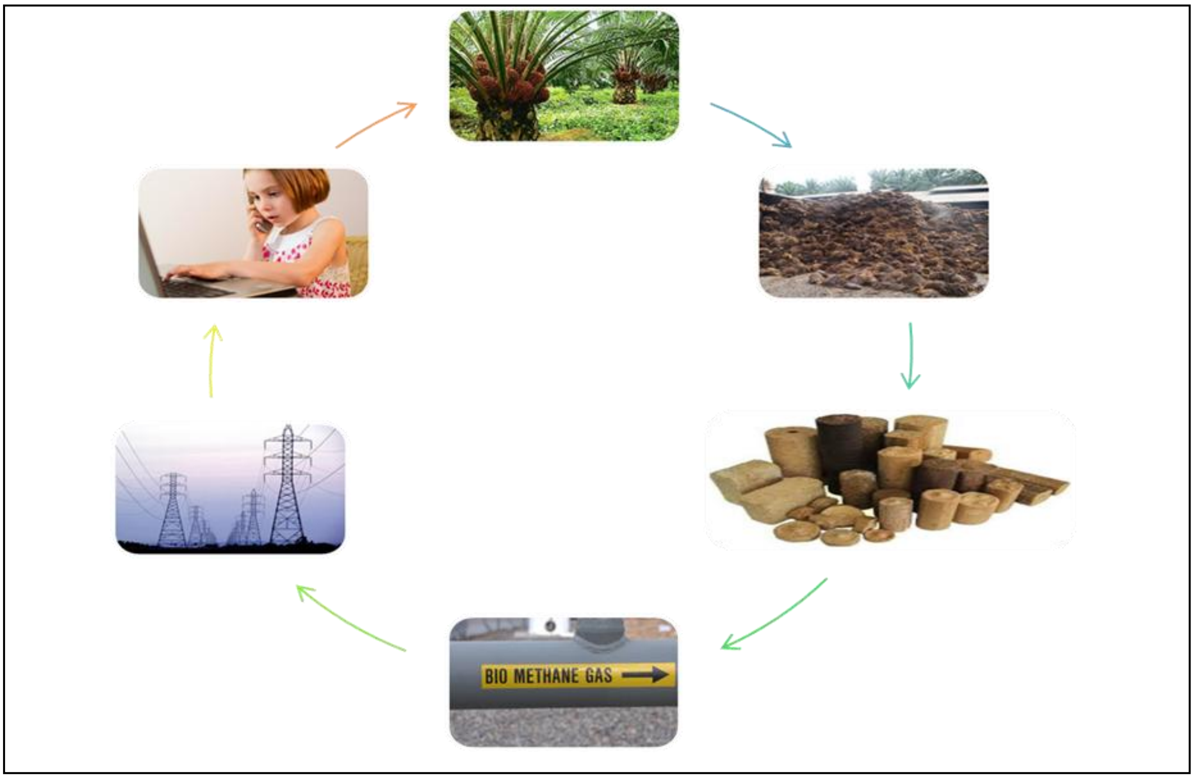


Figure 2. Bio-briquette Usage in Value Chain of Oil Palm Fibre Waste - Electricity Grid Supply

3.2 Closed Loop Supply Chains (CLCS) of Oil Palm Fibre Waste to Electricity Production by Producing Bio Methane Fuel

Previous Bioenergy Value Chain of Oil Palm Fibre Waste to Produce Electricity for Grid Supply been further elaborate by identified variables involved in a closed loop supply chains of this research to understand behaviour overtime of a complex and continuous system. Main sections is divided into four (4) that are supply, inventory, production and distribution. Closed-loop supply chains (CLSC) are supply chain networks that include the returns processes and the manufacturer has the intent of capturing additional value and further integrating all supply chain activities [45]. Variables that been identified in Supply section of oil palm fresh fruit bunch (FFB) are biomass quantity and type of biomass. In inventory section, variables involved are briquette mill cost, inventory risk, handling cost, operational cost, and storage capacity.

Variables involved in production section are volume of methane gas produce, volume of electricity produce, quantity of raw material required for production, levelized cost of electricity (LCOE), and type of conversion technology use. In this study, conversion technology use is chemical reaction technology that is anaerobic digestion. Power production will use gas turbine power plant. Bio methane is used as fuel. Distribution section is allocated for electricity distribution. This section separated by two parts. First is the distribution of electricity from gas power plant to the electrical grid. An electrical grid is an interconnected network for delivering electricity from suppliers to consumers. It consists of generating stations that produce electrical power, high voltage transmission lines that carry power from distant sources to demand centres, and distribution lines that connect individual customers. Second it the distribution of electricity from electrical grid to consumers. Variables identify for this section are independent power produce (IPP) agreement, electricity price and governance policy [46]. Figure 3 shows the proposed closed loop supply chains (CLCS) of oil palm fibre waste for electricity production by producing bio methane fuel. There are four main sections involved that are supply, inventory, production and distribution.

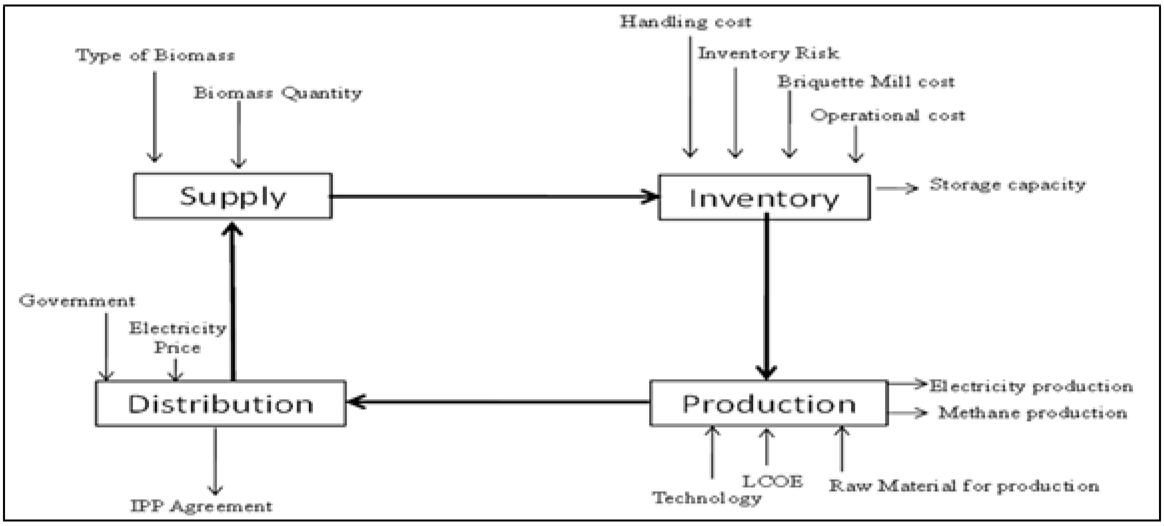


Figure 3. Closed Loop Supply Chains (CLCS) of Oil Palm Fibre Waste for Electricity Production by Producing Bio Methane Fuel

4. Conclusion

Supply chain management is an immensely colossal topic that include many discipline such as operation, materials, logistics and marketing. Distinctive elements of biomasses require categorical approach of supply chain management especially in technology and operation management. Biogas engenderment need categorical approach for product logistic distribution. Biogas logistic will involve certain piping standard operation to be follow to obviate leakage or explosion. The frameworks suggest can be use by researcher to further develop on supply chain perspective for innocuous sustainable biogas production.

5. Acknowledgment

We would like to thanks Centre for Research & Innovation (CoRI), Universiti Kuala Lumpur for expert assistance and financial support.

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