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Research paper

Oil Palm Fibre Waste to Biogas Electricity Production Framework for Mill Operation

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Abstract

One of issue regarding of renewable energy supply chain is source sustainability and reliability to ensure continuous production. The aim of this paper is to suggest the oil palm fibre waste to biogas electricity production framework: mill operation perspective that suit to be practices based on evaluation of current practise of oil palm solid waste and Malaysia's palm oil industry. The framework is based on palm oil mill operation to utilise annually solid waste generate as biomass source for stable biogas electricity production. This conceptual paper is the principal efforts that introduce the usage of storage system for biomass feed input to ensure sustainable stable electricity production from palm oil mill by manipulate their solid waste production. Prospective researchers are put forward to conduct further research to enhance biogas production as alternative for waste treatment strategy.

Keywords: *Green supply chain, Natural-Resource, Waste inventory system, 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 (CO2) gas emitted. Natural gas source that contribute 50% in power generation mixes become among the major fuel source for electricity supply in Malaysia [1-2]. Malaysia government decided to enhance the coal import volume and renewable energy development based on solar, biomass and biogas source [3]. Renewable energy project that have achieved commercial operation from year 2012 - 2014 in Malaysia showed that biomasses source give the highest electricity energy generation (GWh) through incineration approach [4].Research division of Tenaga Nasional Berhad is working on gasification technology based of coal to produce syngas for available gas turbine [2]. Coal is a fuel source that releases a high quantity of CO2 [1] which make methane gas fuel source is more preferable either from natural gas or biogas production. 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 due to fluctuation in supply source, weak handling and low technology efficiency [5-7]. However, a transition of power generation 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 used to full fill the demand for electricity in peninsular Malaysia that the peak demand is 16,901 MW in 2016 [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 [9].

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 [7] 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 [11]. 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 [6, 12]. Malaysia currently marketed significant amount of oil palm biomass waste for biodiesel production to Singapore and Europe [5, 9].

2. Methods and Techniques: Literatures Analysis

Biomass to Biogas 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 [13-15]. Table 1 details up on available conversion energy technology, briquette and palletize.

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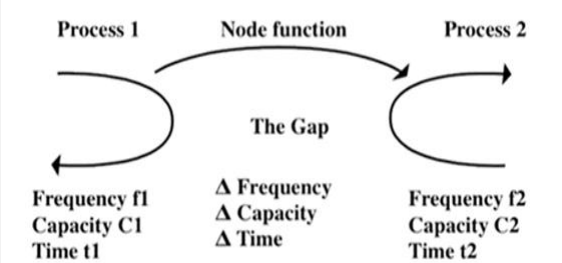
Table 1: Conversion Energy Technology, Briquette and Palletizing

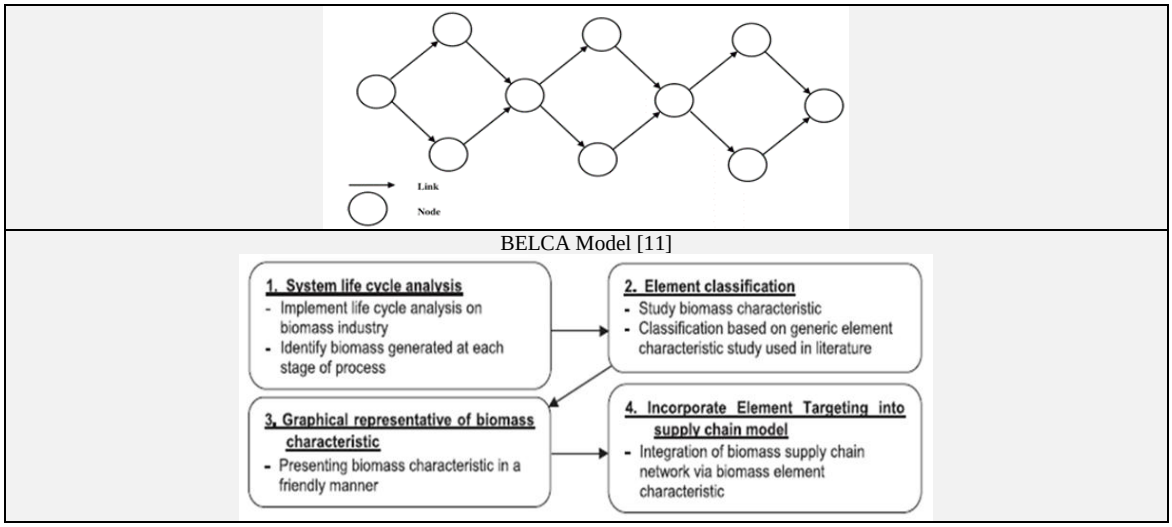
Ref	Method	Description
Thermo Chemical		
[16]	Direct Fired	Involve specific applied technologies that are stoker boilers, fluidized bed boilers and co-firing. Current dominated plant of biomass to produce electricity via steam.
[13, 17]	Co-firing	Burning of mixture of two type of fuel source such as combination of biomass and coal or combination of biomass and natural gas. Common co-firing is natural gas and biogas, pallet biomass and coal.
[18-19]	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.
[20]	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		
[7, 21]	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. Methane gas is used to fuel boilers for heat or generators for electricity. AD process can be used to treat waste and reduces green-house gases.
[7, 21]	Anaerobic Digestion (AD)	AD plant can take place at a location local to where waste is produce which reduce the need for transportation.
[22]	Fermentation	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		
[23-26]	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.
[23-24, 26]	Palletizing	Commonly for biomass wood material only

3. Biomass Supply Chain Management

Knowledge in biomass potential, weak handling, poor logistics, need of modification on engine turbine, low power production, economic conditions, political issues, public awareness, expertise, supply chain co-ordination, modeling and optimizing biomass supply chains for bio refineries are among the barriers have to efficiently solve. So that, type of feedstock, processing plant, distribution system, demand profile, optimal mix ratio, type of conversion technology, supply chain and type of bio product need to be identified to optimize power production [27-29]. Malaysia has been boon with the equatorial monsoon and fertile soil which make this country suitable for many types of plantation such as palm oil industry spans roughly 5.23 million hectares of fields and generates $ 255 million per year [30-31]. Malaysia power green energy industry is facing barriers regarding movement of energy through place, time and existing energy infrastructure. Issues rise in supply chain management are lack of knowledge on technologies related to biomass-to-energy, cost profit analysis regarding due to many type of biomass and energy storage and biomass cultivation and harvesting. Starting on year 2018, all palm oil mills in Malaysia is compulsory to attach methane capture devices to capture methane release from the production. It is suggested that biogas produce from waste palm oil production and methane capture in mills been combine and further research run in term of logistic and management [31]. Theoretical models used shown in table 2. 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 [32-35]. Complexity to produce biomass energy arise huge of research undertake in many study field such as computer simulation [8, 36-38], mathematical algorithm [27], technology management [35, 39], laboratory experiment [9] and supply chain management [28, 40].

Table 2: Theoretical Model

Theoretical Model/Framework
The Function Of The Terminal [41]

A Model Of Transportation [32]



BELCA Model [11]

4. Result and Discussion

Innovation, operation and strategy are essential in technology management. There are three types of flow considered in the supply chains that are physical flow, financial flow and information flow [35, 40]. This research is limited to several dimensions that are focusing only on the palm oil waste biomass physical flow that is material flow starting from biomass source until electricity production. Focus is given on innovation of operation process to ensure electricity supply continuity.

Routing Model of Oil Palm Waste Biomass toward Gas Fuel Supply Chain

Routing Model of Oil Palm Waste Biomass toward Gas Fuel Supply Chain is general a conceptual structures which intend to serve as guide for conducting research activities toward determine objectives and outcome for any palm oil mill case study to treat waste for electricity production. A node refers to a geographical position of activities involve within the supply chain system from supply origin until meet the demand [32]. The nodes could be supply sources, a location of storage, transshipment or processing of goods and terminate point. Hultén [32] state 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 [41].

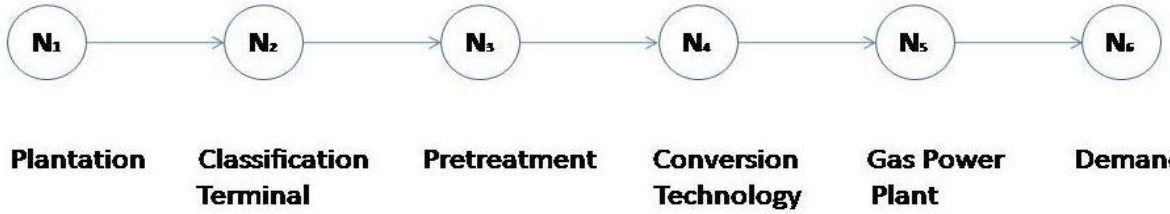


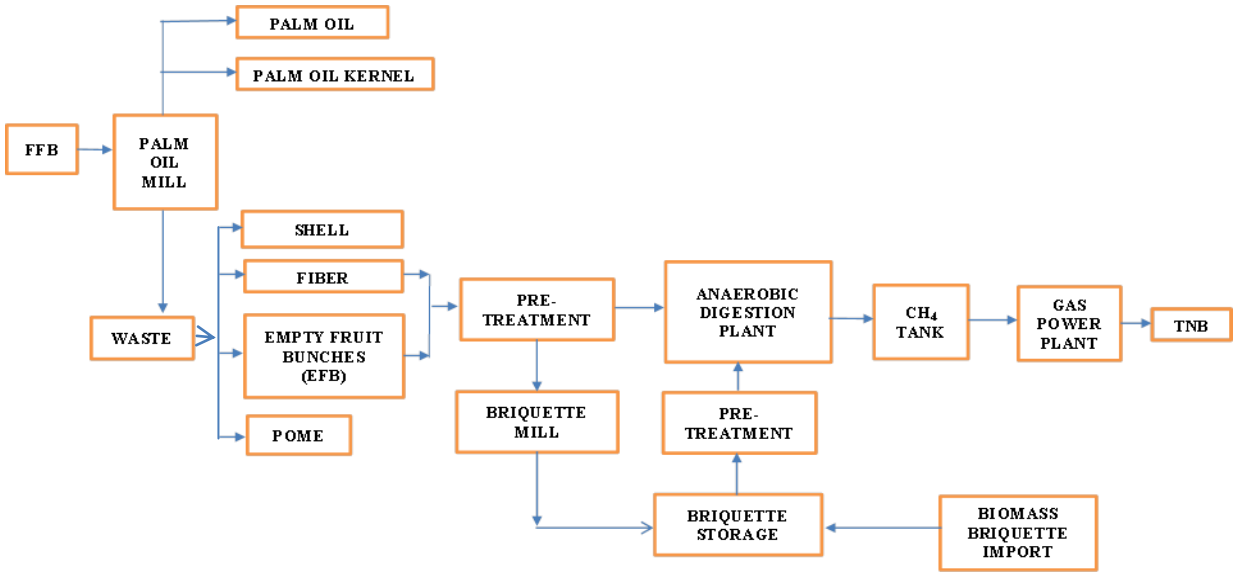
Figure 1**:** Conceptual Route of Oil Palm Waste Biomass toward Gas Fuel Supply Chain [26]

Different type of transportation needed for logistics between each node due to product phase that is either solid, gas or power. Plantation (N1) is palm oil plantation will use lorry to transfer fresh fruit bunch to palm oil mill. Classification Terminal (N2) refers to mill operation that separate oil and waste. Waste will further classified toward Palm Oil Mill Effluent (POME) and Palm Oil Waste Solid Biomass (POWSB). POME is in semisolid phase while POWSB is totally in solid phase (fiber). Classification terminal is very essential to ensure correct feedstock mixture based on the feedstock physical and chemical composition. Pretreatment (N3) section use to prepare feedstock load for Conversion Technology (N4) based on technology type and operation parameter. Pretreatment (N3) may involve several process depend on the type of Conversion Technology (N4) as discuss previous. As example, if Conversion Technology (N4) is direct fired, the oil palm solid biomass use must be dried up. The oil palm solid biomass can be store either in briquette or pallet form. Fuel source produce from Conversion Technology (N4) will be transfer to Gas Power Plant (N5) either via vessel or pipeline based on material phase. Electricity produce at Gas Power Plant (N5) will be wired transfer to customer (N6).

5. Oil Palm Fiber Waste Biomass to Biogas Electricity Production Framework for Mill Operation

There is abundant of oil palm waste biomass in Malaysia that use direct burning technique to produce steam for electricity. The energy production rate is fluctuating due to inconstant fresh fruit bunch yearly production which make mill owners decide to sell POWSB as animal farm food or dumping. This research put forward by changing the conversion technology to anaerobic digestion approach for palm oil waste biomass, with aim to optimize constant energy production. There is various reasons that cause feedstock supply fluctuation such as palm oil plantation cultivation carried out by stages in difference cultivation area, weather, poor transportation, leak of storage properties and plantation is scattered in multiple points such as in small amounts over large areas resulting in covering flows [19].

Figure 2, Oil Palm Fibre Waste to Biogas Electricity Production Framework for Mill Operation is an operation of oil palm waste biomass using anaerobic digestion conversion technology to produce methane gases that use briquetting technique for storage



section. The framework consists of waste source, classification terminal, pre-treatment, solid fuel biomass storage, anaerobic digestion plant, compressed tank for methane gas before entering gas fired power plant to generate electricity. The waste use is oil palm fiber from empty fruit bunch and mesocarp from palm oil manufacturing. Classification terminal will split fiber source with other waste that are kernel shell, POME, trunk and frond. Pre-treatment terminal for this framework suggested briquetting technique for storage surplus waste that will involve dry up to ensure long lasting storage and shaping for entirely utilize the store area. The storage has two function that are to supply feedstock for anaerobic digestion plant when there is insufficient waste supply from palm oil mill and the surplus storage can be export in biomass briquette form. Anaerobic digestion technique is suggested due the anaerobic process that will produce high amount of methane gas compare to any other conversion technologies available for waste biomass treatment. The methane gas produced can be consuming same as natural gas due to the same chemical composition and physical characteristic. Plus, the cost of biogas produce from anaerobic digestion is low due to no heat applied and mechanical machine in the process. Methane tank is needed to ensure continuous stabile biogas flow to gas turbine for electricity production. The aim of this system framework, is to obtain the maximum profit and able to supply stable electricity power through the year to custome

Figure 2: Oil Palm Fibre Waste to Biogas Electricity Production Framework for Mill Operation

6. Conclusion and Future Research

Critical analysis had been carry out on current practice in Malaysia's electricity production, biogas fuel, biomass conversion technologies and oil palm waste potential to develop the Oil Palm Fibre Waste to Biogas Electricity Production Framework for Mill Operation. The framework applied AD technologies and briquetting storage system to ensure continuous electric grid supply. The suggested conceptual framework had improve current practise, explaining new methods, and guiding towards the emerging integrated of available technology for fully utilize energy potential from oil palm solid waste. This study, in hope will leads to further works, giving inspirations and insights to other renewable energy researchers to enhance the energy security, energy sustainability, health environment and economic sustain by ensuring green energy demand fulfilled.

References

[1] World coal association, (2015)
[2] TNB annual reports (2014)
[3] Michael Cheang, & Cheang, M. (2007). Wind, Sun and Diesel. The Star (Malaysia). Retrieved from http://thestar.com.my/lifestyle/story.asp?file=/2007/9/25/lifefocus/18881160&sec=lifefocus
[4] Shafie, S. M., Mahlia, T. M. I., Masjuki, H. H., & Andriyana, a. (2011). Current energy usage and sustainable energy in Malaysia: A review. Renewable and Sustainable Energy Reviews, 15(9), 4370–4377.
[5] EIA. Energy supply security 2014 Part 2 (2014)
[6] EIA. Energy Security (2015)
[7] Union of Concerned Scienties. (n.d.). How Biomass Energy Works | Union of Concerned Scientists. Retrieved November 5, 2015, from http://www.ucsusa.org/clean_energy/our-energy-choices/renewable-energy/how-biomass-energy-works.html#.Vjrt4m7s7vB
[8] Villada, J., &Olaya, Y. (2013), A simulation approach for analysis of short-term security of natural gas supply in Colombia. Energy Policy, 53,pp.11-26.
[9] Ali, R., Daut, I., &Taib, S. (2012), A review on existing and future energy sources for electrical power generation in Malaysia. Renewable and Sustainable Energy Reviews, 16, 6, pp.4047–4055
[10] Shafie, S. M., Mahlia, T. M. I., Masjuki, H. H., &Andriyana, a. (2011) ,Current energy usage and sustainable energy in Malaysia: A review. Renewable and Sustainable Energy Reviews, 15(9), pp.4370–4377.
[11] Hsion, C., &Loong, H. (2015), Biomass supply chain optimisation via novel Biomass Element Life Cycle Analysis (BELCA).Applied Energy.
[12] Hosseini, S. E., & Wahid, M. A. (2013). Feasibility study of biogas production and utilization as a source of renewable energy in Malaysia. Renewable and Sustainable Energy Reviews, 19, 454–462.
[13] CEA. (2014). Environmental Technology Energy from Biomass Energy from Biomass.
[14] Hsion, C., & Loong, H. (2015). Biomass supply chain optimisation via novel Biomass Element Life Cycle Analysis (BELCA). Applied Energy.
[15] Malaysia to Become the Biogas Hub of Asia « Malaysian Biotechnology Corporation. (n.d.). Retrieved August 25, 2015, from http://www.biotechcorp.com.my/media/malaysia-to-become-the-biogas-hub-of-asia/
[16] Peter Fah Kui, C., & Hjh. Nazariah, I. (2011). Renewable. Tenaga Link, 1/01, 1–20.
[17] Smith. (2006). Biomass Conversion Technologies. EPA Combined Heat and Power Partneship (pp. 30–61).
[18] National Film Board of Canada, & Canada, N. F. B. of. (n.d.). Bate's Car: Sweet as a Nut. NFB.ca. Retrieved from http://www.nfb.ca/film/bates_car_sweet_as_a_nut/

[19] Tanksale, A., Beltramini, J. N., & Lu, G. M. (2010). A review of catalytic hydrogen production processes from biomass. Renewable and Sustainable Energy Reviews, 14(1), 166–182. http://doi.org/10.1016/j.rser.2009.08.010
[20] U.S. Department of Energy. (2013). Feedstock Supply and Logistics : Biomass as a Commodity. USDE Energy Efficiency & Renewable Energy. Retrieved from biomass.energy.gov
[21] Faizal, H. M., Latiff, Z. A., Wahid, M. A., & Darus, A. N. (209). Physical and Combustion Characteristics of Biomass Residues from Palm Oil Mills, 34–38.
[22] Burmeister, F., Senner, J., Tali, E., Institut, G., & Essen, V. (2012). Conditioning of Biogas for Injection into the Natural Gas Grid (print edit). China: In Tech.
[23] Hengeveld, E. J., van Gemert, W. J. T., Bekkering, J., & Broekhuis, A. A. (2014). When does decentralized production of biogas and centralized upgrading and injection into the natural gas grid make sense? Biomass and Bioenergy, 67, 363–371.
[24] Iskov, H., Backman, M., & Nielsen, H. P. (2010). Field Test of Hydrogen in the Natural Gas Grid. In 8th World Hydrogen Energy Conference, WHEC 2010. Retrieved from http://juser.fz-juelich.de/record/135367
[25] SEDA . (n.d.). Retrieved August 26, 2015, from http://seda.gov.my/biogas.html
[26] Zakaria, I. H., Ibrahim, J. A., & Othman, A. A. (2017). Routing Model of Oil Palm Fibre Waste toward Gas Fuel Production Supply Chain Management : Malaysia Industry. International Journal of Supply Chain Management, 6(2), 75–80.
[27] B. Velazquez-Marti, E. F.-G. (2010), Mathematical algorithms to locate factories to transform biomass in bioenergy focused on logistic network construction. Renewable Energy, 3, 9, pp.2136–2142.
[28] Balat, H. (2010). Prospects of biofuels for a sustainable energy future: A critical assessment. Energy Education Science and Technology Part A: Energy Science and Research, 24(2), 85–111. Retrieved from http://www.scopus.com/inward/record.url?eid=2s2.077949876729&partnerID=tZOtx3y1
[29] Husain, Z., Zainac, Z., & Abdullah, Z. (2002). Briquetting of palm ÿbre and shell from the processing of palm nuts to palm oil, 22, 505–509.
[30] Vassilev, S. V., Baxter, D., Andersen, L. K., & Vassileva, C. G. (2010). An overview of the chemical composition of biomass. Fuel, 89(5), 913–933.
[31] VIV Asia Biogas Conference - VIV Asia. (2015). Retrieved November 9, 2015, from http://www.vivasia.nl/en/Bezoeker/Special-Events/Biogas/Biogas-Conference.aspx
[32] Hultén, L., (1997) , "Container logistics and its Management", Chalmers University of Technology.
[33] Kang, S.-H., Kang, B., Shin, K., Kim, D., & Han, J. (2012). A theoretical framework for strategy development to introduce sustainable supply chain management. Procedia - Social and Behavioral Sciences, 40, pp.631–635.
[34] http://www.apics.org/sites/apics-supply-chain-council
[35] Ba, B. H., Prins, C., & Prodhon, C. (2015). Models for optimization and performance evaluation of biomass supply chains : An Operations Research perspective. Renewable Energy, 1–13.
[36] Saifudin, A. M., Zainuddin, N., Bahaudin, A. Y., &Zalazilah, M. H. (2015), Enriching Students Experience in Logistics and Transportation through Simulation.
[37] Salman Ahmad, & Mat, R. (2014). Using system dynamics to evaluate renewable electricity development in Malaysia. Kybernetes, 43(1), 24–39.
[38] Dilek Cetindamar, Robert Phaal, David R., Probert,. (2016), Technology management as a profession and the challenges ahead, Journal of Engineering and Technology Management , Vol 41, Pg1-13,
[39] CEA. (2014). Environmental Technology Energy from Biomass Energy from Biomass.
[40] Izatul, H. Z., Jafni, A. I., & Abdul, A. O. (2016). Supply Chain Management Model of Wood Biomass Producing Hydrogen Fuel for Malaysia's Electricity Industry. International Journal of supply Chain management, Vol. 5, No. 2, 85-93.
[41] Lumsden, K.. (2006), Logistikensgrunder, Svenska, ISBN: 9789144081298