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Talking Points of Green and Sustainable Palm Oil Mill System in Malaysia

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***Abstract:** Todays, the palm oil milling industry (POMI) has been given serious attention due to environmental issues that arise from the milling processes. Greenhouse gas emission, wastewater quality, waste management plan and energy efficiency are the main POMI issues that contribute to the environmental problems. Critically, this issues could bring a serious impact in sustaining Malaysia palm oil industry in current global economic competitiveness. Moreover, the stringent trading standard for palm oil industry has forced the palm oil producer to align and fulfilling the requirements accordingly. In this short article, the overview of POMI system in Malaysia were elaborated. Besides, the strength and weaknesses of the Malaysia POMI system were highlighted in giving understanding of current condition. Furthermore, the challenge and potential in greening POMI system were discussed in ensuring sustainable future of POMI in Malaysia.*

***Keywords:** Economic competitiveness, Milling industry, Palm oil, Sustainable*

I. INTRODUCTION

Malaysia is the second largest producer of palm oil in the world, contributing 19.96 million tonnes of the global palm oil production [1]. Over a span of 9 years, oil palm plantation area in Malaysia has expanded to 5.81 million hectares in 2017[2]. In tandem with the growth in the oil palm plantation area, the number of the palm oil mills also increases to 454 mills in 2017. By 2017, there are 53 palm oil refineries (total annual capacity of 27.33 million tonnes), 45 palm kernel crushers (total annual capacity of 7.27 million tonnes) and 19 oleo chemical plants (annual processing capacity of 2.67 million tonnes) in operation throughout Malaysia [3]. The biggest oil palm plantation is located in East Malaysia, namely the state of Sarawak with total plantation area of 1.56 million hectares (26.8%), followed by Sabah with 1.55 million hectares (26.6%) and the rest of the states in West or Peninsular Malaysia with 2.7 million hectares (46.6%) [4].

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Currently, Sabah has the highest number of oil palm mill (130 mills), followed by Sarawak (80 mills), Pahang (72 mills), Johor (64 mills), Perak (45 mills), Selangor (21 mills), Negeri Sembilan (16 mills), Terengganu (13 mills), Kelantan (11 mills) and the rest of other states (less than 10 mills) [5]. These plantations are largely based on the estate management system, owing to the fact that most of them is owned by private estates, covering 3.5 million hectares or 61% of the plantation area. Meanwhile, the remaining share is owned and managed by independent smallholders (17%), government authorities such as Federal Land Development Authority (FELDA), Federal Land Consolidation and Rehabilitation Authority (FELCRA) and Rubber Industry Smallholders Development Authority (RISDA), each with 12%, 3% and 1% respectively, and last but not least, state schemes or government agencies (6%) [1, 5].

Over last 10 years, Malaysia has maintained its position as the world's major palm oil producer. The palm oil industry is progressively growing despite the fluctuation of crude palm oil (CPO) and crude palm kernel oil (CPKO) prices [6]. The export revenue of palm oil products is huge, making billions of ringgits annually, hence contributed significantly to the country's overall national economy earnings [7]. It should be noted that the palm oil industry is also an important source of income for many of Malaysians. The palm oil plantations and mills have provided numerous jobs opportunity and has raised the standard of living of small and rural communities in the country [7]. Particularly, the industry has become the lifeline to covered income and livelihood. Therefore, it is important for the palm oil industry to continually grow and thrive in the international market in order to preserve the country's economic stability and social well-being. This industry should adopt various measures to stay relevant and competitive in the global market.

Nevertheless, in the recent years, palm oil industry has been consistently normalized as a bad agriculture industry that causes severe environmental problems. The development of the oil palm process was claimed not environmentally sustainable due to the contribution of green gas house (GHG) emission, pollution of wastewater, high of carbon foot print and low energy efficiencies of milling operation [8-10]. Moreover, this argument has forced the oil palm industry is also subjected to many certification requirements compared to other oilseed producers. Therefore, this short review is aiming to discussed and elaborate causes and potential solution for greening and sustaining the palm oil mill system in Malaysia.

II. MALAYSIA PALM OIL MILL SCENARIO

Since 1990, the number of Malaysia palm oil mill in operation has expanded from 261 to 454 of mill in 2017 [11]. Throughout the years the increased of the palm oil mill are mainly contributed by the increment of new plantation area. As reported, more than 100% increases in palm oil planted area from 2.03 million hectares in 2009 to 5.19 million hectares in 2018 [2]. The increment of the planted area also increased the capacity of fresh fruit bunch (FFB) produced in mill operation. As shown in Table 1, the increased of mills in operation has increased the total capacity of palm oil produced begin in 2009 until 2018. Nevertheless, the capacity of extracted palm oil produced in each mill are different to each other. As reported by Azman 2014 [12], each palm oil mill was design based on the ability of the mill to process a specific amount of FFB per hour. In this regard the palm oil mill is separated into two categories namely small (less than 20 tonnes/hour) and large (more than 20 tonnes/ hour) palm oil mill [12]. Besides, there are mill operations that are located in integrated and isolated area which also differentiate the amount of palm oil mill capacity.

Table. 1 Number of operating mills and total capacity in Malaysia (2009- 2018) [11]

Year	Number of Mills	Capacity (tonnes FFB/ Year)
2009	261	42,874,000
2010	421	97,380,600
2011	426	99,852,400
2012	432	102,342,400
2013	434	104,090,400
2014	439	105,758,400
2015	445	108,396,400
2016	453	110,326,200
2017	454	112,187,800
2018	451	112,422,000

The extraction of palm oil involves numbers of process in milling operation. In this operation, the fresh palm oil was produced after six main stages to fully complete the extraction process. Figure 1 shows the complete stages of palm oil extraction from fresh fruit bunch (FFB) to produce crude palm oil (CPO) and palm kernel oil (PKO) as a primary product with biomass as a secondary product. Conventionally, the palm oil mill extraction is comprised with main operation unit that include of sterilizer, mechanical trammel, press, separator, purification and storage unit [13]. Each operation unit is mainly design to maximize the extraction rate of the palm oil from the FFB at minimum utility consumption. Besides, this conventional extraction process is normally operated with low process losses and simple operating maintenance. Practically, the main aim of palm oil extraction system design or innovation is to fulfill high production and provide low operation cost. Nevertheless, this palm oil mill operation system is contributing to various environmental issues that require to be resolved.

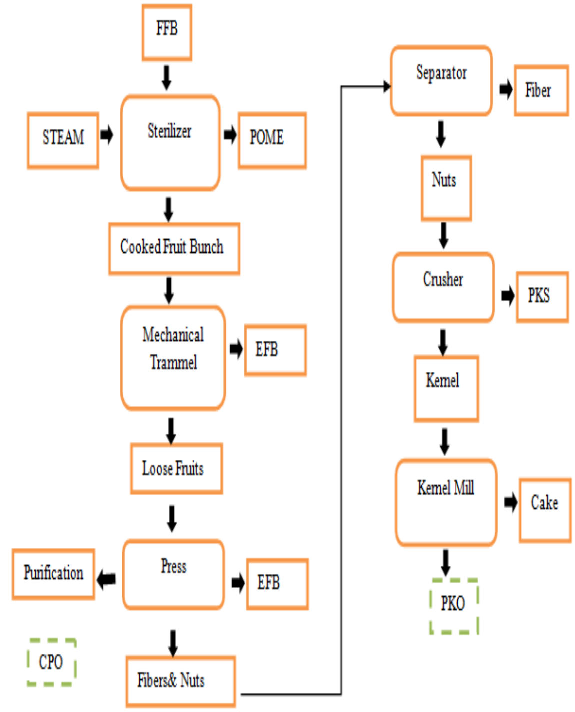

Fig. 1 The extraction process of palm oil fresh fruit bunch (FFB) [13].

Green House Gas Emission

The greenhouse gases (GHG) are exists from various process of palm oil mill operation. Transportation, chemicals and raw material acquisition, energy used, palm oil mill effluent (POME), biomass decomposition and burning are the process sources of the GHG emissions in palm oil mill operation [14]. These released GHG contain water vapor (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) which greatly affect the earth temperature by the thermal radiation reflection [15]. Practically, POME and operation energy utilities are the primary sources of the released GHG to the environment. As reported by Hosseini et al. (2013) [16], POME, a large by-product of the palm oil process releases high amounts of GHG. In average, 1.5 m^3 of water is required to extract one tons of fresh fruit bunch, and half of the liquid is converted waste water which consist of soluble organic components and suspended materials of palm oil fruits [17]. Meanwhile, the combustion process for steam boiler utilizing the palm oil mill biomass residue produce the gaseous and particulate emissions [16]. High boiler's thermal condition increases the emission concentration to the atmosphere. However, in the excess of air to fuel ratio, the emission will be less concentrated [8].

In this regard, the treatment and conversion of energy in efficient system could reduce the high emission of GHG to the atmosphere. Although there is regulation amended specifically for air pollution of palm oil mill, the enforcement and commitment to fulfill the standard air quality are still far from environment target. In recent updates, department of environment (DOE) has implemented the new regulation of air pollution in palm oil mill that started on April 2019. Under this regulation, the palm oil miller is required to comply with emission limit values of particulate matters (PM) of 150 microgram/m^3 by mitigating and adapting various air pollution technology DOE [18]. Nevertheless, the implementation will be challenging due to high capital investment for the milling industries to install and operate the system in order to follow the standard and regulation enforced by DOE. As reported by DOE [18], currently only 52 of palm oil mill that complied with the new enforcement for air pollution reduction.

Wastewater Treatment

The wastewater treatment for palm oil mills are primary focus on the POME treatment. The excessive discharge of untreated POME to water body will damaged the ecosystem due to depletion of oxygen and suffocation to the aquatic life [20]. POME discharge is regulated under the Environmental Quality Act (1974), with the set limit of 100 parts per million (ppm) for BOD levels before the mill operation can discharge the effluent into the surrounding environment [21]. However, the recent enforcement by DOE has set a stringent standard A discharge limit with 20ppm discharge limit which is a big challenge to most mills to comply with the conventional technologies which are having inconsistent quality of treated wastewater. The untreated POME usually contained high BOD up to 100 times higher than domestic sewage as well as high COD and suspended solid [22].

In Malaysia, the operative system of POME treatment is using the facultative aerobic pond system. Practically this system was adopted by almost 85% of mills in Malaysia that is also known as open ponding system [17]. Moreover, this system has been pointed as the second largest methane generator next to municipal solid waste landfill system [23]. Through the aerobic open ponding system, the methane (CH_4) gas is freely released to the atmosphere over the past years. However, since 2010 under the economic transformation program (ETP), the application of biogas capturing from POME has been initiated through the palm oil national key economic area (NKEA) as an economic and environmental agenda. Besides the initiative has been further driven under renewable energy act (2011) [24]. Unfortunately, the impact of the NKEA strategy has only shown significant results in the early years of its implementation.

Table 2 shows the trend of POME biogas application from 2007 to 2016[25]. The depletion trend of biogas plants operation shows the inconsistency of the system performance to be maintained by the palm oil millers. Besides, the expiry period of clean development mechanism (CDM) commitment also giving effects to the reduction. Consequently, the mandatory action has been taken in 2015 for every new mill and old mill expansion application to install full AD biogas system facilities in ensuring commitment from the millers. The system is expected to generate biogas that is converted to electricity and produce wastewater that is able to be used in boiler system. Nevertheless, the application outcomes for the sustainable system of POME treatment is still small and inconsistent.

Table. 2 Trend of POME biogas application from 2007 to 2016 [25]

Year	Number of Biogas Plant Install	Total Biogas Plant in Operation	Flaring	Combine Heat Power	Electricity Generation	Grid Connected
2007	1	2	2	0	0	0
2008	3	5	2	1	2	0
2009	5	10	7	1	2	0
2010	0	10	7	1	2	1
2011	10	20	9	4	7	1
2012	9	9	3	3	3	2
2013	5	5	1	3	1	1
2014	4	9	5	1	3	3
2015	0	9	5	0	4	5
2016	3	12	7	0	5	7

Waste Management

The FFB processing generates abundant of residual waste of biomass, which is nearly 75 % of its deliverables to the palm oil mill [9]. In actual, by taking 2017 as a baseline (101 million tons of processed FFB), the amount of biomass generated about 75.75 million tons of waste in a form of liquid, solid and gas [5].

This large quantity of waste is having variety of biomass that can be categorized into empty fruit bunch (EFB), mesocarp fiber (MF) and palm kernel shell (PKS). As shown in Figure 2, these biomasses are having wide potential in variety of applications such as bio fertilizer, renewable energy, bio composite products and phytol-chemicals products [26]. The palm oil biomass bio fertilizer was produced from bioconversion of EFB and POME into composted organic waste. These bio fertilizers are capable providing beneficial microbes to release the nutrients to the plants [27]. Meanwhile, the residues of other components of palm oil tree such as trunks and fronts were cut and compressed into other bio composite products [26]. Moreover, the derivation of the palm oil residuals could also be further converted to other phytochemical products [28]. As reported by Tan et al. (2012), the high value of palm press fibers (PPF) extractions is having high potential applications in nutraceutical, pharmaceutical and cosmeceutical industries. These aqueous palm oil by-products contained valuable bioactive compounds (phenolics antioxidants) that could be intensified for health benefits products [29]. However, the excess of processed biomass from the FFB were mainly utilized as renewable energy sources in the milling processes. The EFB and mesocarp fiber were widely being used as a feedstock for steam boiler utilities [8]. Particularly, the solid palm oil biomass (EFB, MF and PKS) are having huge potential for direct or synthesized biofuel into power generation. Nevertheless, these huge potential sources remained not fully untapped and utilized. Most of the millers applied the biomass sources for co-firing of the steam boiler as to provide heat and power to the mill processes. However, this approached is not fully efficient in providing energy with inconsistent thermal efficiency that requires excess of fuel sources [8]. In this present concept, the palm oil waste management was handled in improper disposal method. The excess of naturally degraded palm oil biomass could contribute to various environmental implication that may result in occurring of disease problems and ground water contaminations [30].

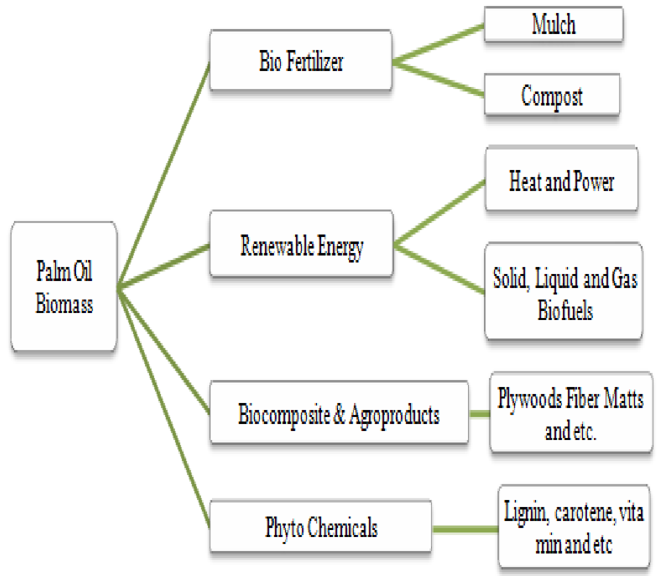

Fig. 2 Potential and variety applications of biomass. (MPOC)

Energy Efficiency

Most of the palm oil mill boiler system in Malaysia are using low efficiency pressure boiler with cogeneration efficiency below than 40% [29]. Primary, the low consistency of the process temperature and the inability of the turbine to cope with the process demand are the main cause for the inefficient boiler system operation [8]. This low energy efficiency was also related to the utilization of unstripped bunches and low crop supply for the boiler operation. The inconsistency of the process has brought the milling operation to various environmental concern. As reported by Hanafi et al. (2014) [31], the air pollution released from the boiler has poses the health and environmental impact. The inefficient of the boiler combustion system has significantly affected the clean atmosphere due the release of particulate matter that contained various concentrated gases that is harmful to the surroundings. In addressing the issue, the combined heat and power (CHP) system is the ideal approached in resolving the drawbacks of rapid large fluctuations in demand and high consumption of process steam related to the sterilization process. However, presently none of the palm oil mill are consistently implementing this superior performance of palm oil energy system. The development of policy and regulations could strengthen the enforcement of implementation of the system. Besides the real energy efficient design of renewable energy system should be physically develop by Malaysian expertise as to ensure the continuous performance and consistency.

III. CHALLENGE AND POTENTIAL

Malaysia palm oil mill industries (POMI) has extremely has contributed to the consistent annual outcome of world palm oil productions.

The efforts of improving the productions by increasing the oil extraction rate has become the most priority of all POMI in Malaysia. Each of the particular challenge in gaining high oil production outcomes has been focused and resolved intensively throughout the past years. Nevertheless, the environment and sustainability of the POMI is the real continuous challenge that accompanied POMI along the success achievement of annual oil productions. In order to ensure the real sustainability of Malaysia palm oil industry in the future, the environmental and sustainability issues of POMI should be resolved wisely by structuring the challenge and potential accordingly. The challenges and potentials of greening and sustaining the Malaysia palm oil mill system are listed as below:

Challenges

1. The life cycle assessments (LCA) is evaluation tool of environmental conditions that important for action plan and management. As ruled by Environment Protection Agency (EPA), Malaysia was not qualified for renewable fuel market due to low GHG lifecycle reduction (17%) [8]. Geographically, Malaysia palm oil mill are scattered and mostly distributed in rural area. The high level of GHG emission in palm oil mill are primary contributed by transportation, energy used and POME. The transformation of this old operation system palm oil mill are really crucial in greening the operation system. However, the remediation process will take longer time as to negotiate and providing the best economic solution to the private millers in making the transformation effort.
2. Green renewable energy is meaningless until the electricity grid connected to the mills are generated from the renewable energy sources. Individually, the amount of biomass feedstock and POME may not reliable for the mill to consistently support the operation system using the renewable energy power. Besides, the location of the mills is also contributing to the constant excess of renewable energy sources. The competitive of raw biomass purchase value for various application could also retarded the effort. Moreover, the effort of centralizing the sources may not consistence due to the none existing protection policy.
3. The conversion of open pond for POME treatment system into integrated biogas plant has been conducted previously under NKEA program. There are only 55 mill have been installed which represent 12% from the total available mill [25]. The main challenge to sustaining the program were reported due to limited and inadequate fund for returning payment to renewable energy generator. Therefore, most of the millers have experienced first renewable energy effort and stick on the negative perception. Moreover, the availability of low cost conventional method for energy sources has make the condition more challenging.
4. The superior performance of the operation system is very dependent on the technology adaptation. The lack of expertise and local manufacturer for the implemented technology has resulted inconsistence performance of the system. Besides, the current implemented operation system in the palm oil mill is difficult to be maintained continuously. The dependent of outsider expertise has resulted poor performances of the green and sustainable technology.
5. Regulation and restriction are the main supplementary tool for the POMI green and sustainable achievement. Stringent standard of environmental preservation has been taken to reduce and eliminate the pollution occurs from the POMI. However, this effort remains challenging due to location and number of mills operated that difficult a consistence regular inspections.

Potentials

1. The advantage of huge reservoir of palm oil biomass has not been used in improving the sustainability of palm oil industries should be utilized. In diverting these weaknesses, the generation of clean energy utilizing the palm oil biomass to be decarbonized and increased the lifecycle reduction above the 20 % qualification level is the most significant way.
2. A holistic and complete renewable energy policy could be a real solution to the environment and sustainability challenge of POMI. This policy should tackle the ownership and economic issue that rebound the effort of miller in giving strong commitment to the greening programs.
3. The Malaysian depth research and investigation should be standing as a fully established research. Those significant finding that could potentially provide better system stability to the national industries operation should be exposed and utilized.
4. The high number of POMI in scattered location of Sabah and Sarawak could potentially be organized in coordinating a centralize biomass power plant development for renewable energy effort. This huge scale of biomass power plant could able to return as an offset renewable power to the electricity grid in all POMI which supply the renewable biomass sources. Particularly, all the internal boiler system that polluted the environment could be ended as the offset of clean electricity supply.
5. The open ponding system of POME treatment giving significant potential of huge renewable energy potential. The high methane production from the anaerobic digestion (AD) system could be further optimized with providing two phase AD for better system stability compared to the current system. This significant source could be designed as an internal renewable power resource for POMI that received electricity from centralized biomass power plant.

IV. CONCLUSIONS

This paper provides a short review for POMI environment sustainability. In overview Malaysia POMI has shown significant drawback of environment conditions. Presently, Malaysia has continuously received negative perspective of its POMI. In improving the POMI condition, there are several talking points that should be address urgently by Malaysia government. A well structure of planning and roadmap is a key for sustaining the POMI futures. Ideally, the development of large scale and centralized biomass power plant are the significant assess ways to greening and sustaining the Malaysia palm oil milling system. This aim could be achieved by establishing a holistic national renewable policy for palm oil industries. POME and palm oil biomass are the two main pillars that could greening and sustaining the milling system. The investment for utilizing these most valuable palm oil waste products as the energy generation system is not only providing the benefit for environment but also improving the social and economy of rural live hood.

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