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# The Future of Biogas in the Malaysian Palm Oil Industry: Why Need Methane Capture?

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## INTRODUCTION

Malaysia is the world's second largest producer of palm oil. In 2019, a total of 19.86 million tonnes of crude palm oil (CPO) was produced from 98.28 million tonnes of fresh fruit bunches (FFB) processed by 452 palm oil mills, with an export earnings of RM63.73 billion from 5.90 million hectares of oil palm planted areas (MPOB, 2020). During palm oil extraction, a wastewater stream, palm oil mill effluent (POME), is generated abundantly. Based on the POME: FFB mass ratio of 0.67:1, the industry could generate an approximate 65 million tonnes of POME in a year. The anaerobic digestion (AD) of POME, through a series of open ponding system (*Figure 1*), emits biogas - a greenhouse gas (GHG) of about 65% methane (Loh *et al*., 2017), which is untapped and then released into the atmosphere. If otherwise it is produced and trapped, it becomes a replenishable energy source for the country.

The history of biogas development in the palm oil industry was dated back in the early 1980s, with the first biogas plant established at the Tennamaram Oil Mill, followed by the Keck Seng Palm Oil Mill. Initially, the slow development was hindered by the extensive investment required, the lack of technical expertise (know-how) and an ineffective implementing framework (Kushairi and Parveez, 2017; Loh *et al*., 2017). The industry's far-sighted vision during that time was to maximise the use of in-house renewable energy (RE) source, which received a boost when Malaysia ratified the Kyoto Protocol in 2002. Research revealed that 28 m$^3$ of biogas could be generated from one m$^3$ of POME (Ma *et al*., 1994), showcasing the huge potential of generating RE via biogas trapping to enhance the sustainability of the industry. In line with this, an important development took place for the generation of biogas-based energy from the palm oil industry. In 2010, the capturing of biogas from POME was further emphasised and facilitated through a national agenda (ETP, 2010). This implementation marks the start of an important industry's initiative towards environmental sustainability and future bioeconomy development.

The Malaysian oil palm industry has had a 100-year of development since 1917 (Kushairi and Parveez, 2017). This industry has always been negatively alleged for two main issues: nutrition and sustainability. The propagated negative facts that palm oil is highly saturated, thus its consumption increases blood cholesterol level and cardiovascular risk, and that oil palm is an environmentally- and socially-unfriendly crop causing deforestation, illegal logging, destruction of orangutan habitats, peatland degradation, loss of biodiversity, *etc*. plus the current pressing issue associated with biogas emissions from POME, are unfounded and widely manipulated by vested interests in certain countries to safeguard their industries. The positive attributes of palm oil *e.g*. an almost equal mix of saturated/unsaturated fatty acids indicating a stable oil with a long shelf life, trans fat-free, oil palm sustainable cultivation via good agricultural practices, to name a few, along with the more recent biogas trapping activities undertaken by the industry, to some extent, disseminated and publicised, but in vain to convince the vast majority of the public. More efforts are indeed necessary, and the industry needs to be well-rounded to tackle these issues back-to-back.

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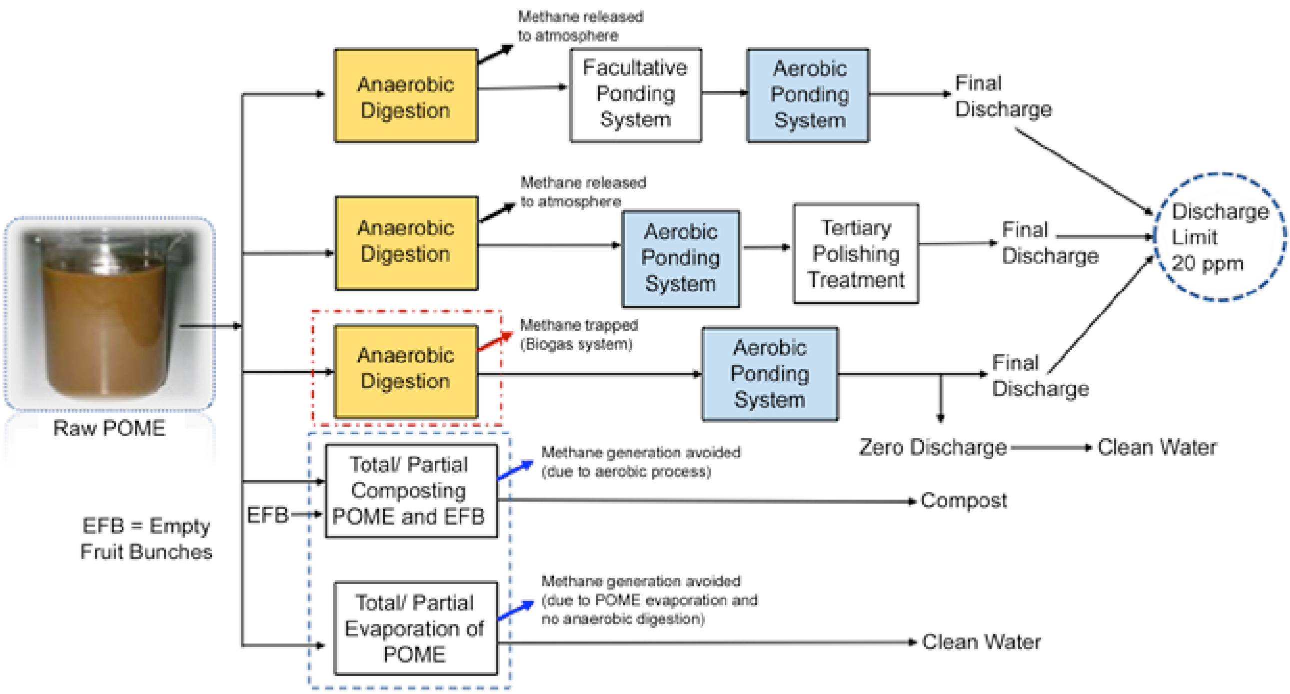



*Figure 1. Different approaches in palm oil mill effluent (POME) treatment.*

## POLICY AND INCENTIVE

The industry, through 20-30 years of hardship, pain and lessons learned plus the experience gained, has managed to build 125 biogas plants (Loh *et al*., 2019a) alongside conventional POME treatment system. The biogas implementation initiative, both the trapping and utilisation aspects, is a green endeavor to reduce GHG emissions. Mitigating climate change through biogas trapping has been mandated via MPOB circular, covering new and existing palm oil mills that need throughput expansion since 2014 (MPOB, 2013). There is no regulation as yet for existing mills. The 2020 target of having all palm oil mills to equip with biogas trapping facilities is merely an envisagement of the government aiming for economic transformation.

There is no policy directly linked with biogas capture for environmental sustainability but several others associated indirectly are: 1977 - Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations; 1978 - Environmental Quality (Clean Air) Regulations; 1986 – Promotion of Investment Act; 2001 - Fifth Fuel Policy; 2009 - Green Technology Policy; 2009 - National Policy on Climate Change, and 2010 - Renewable Energy Act. Several financial assistance schemes *e.g.* feed-in tariff (FiT), RE tax incentives, green technology financing scheme (GTFS), venture capital financing, BioNexus-status tax incentives, *etc.* are put forth to encourage environmental sustainability endeavors including biogas trapping. The fiscal incentives made available under the Promotion of Investment Act 1986 for biogas trapping as RE include pioneer status (PS), investment tax allowance (ITA), import duty, sale tax exemption, *etc.* (*Table 1*). Applications received by 31 December 2020 are eligible for these incentives. As of August 2013, about 16 biogas manufacturers were granted with tax incentives for biogas trapping (pers. comm.). We saw huge potential to develop biogas-related businesses in the future taking advantages of possible tax rebate. Although the GTFS is made available to benefit companies going green since 2010, it falls short of the bankability requirements for financing as it lacks coherence amongst the players and risk management knowledge to push for such national development.

Earlier, the Clean Development Mechanism (CDM) adopted by Malaysia during Kyoto Protocol had enabled biogas trapping an additional activity quite actively pursued by the palm oil industry. As of December 2014, a total of 1.24 million tonnes $CO_2$ eq. has been sold as carbon credits; huge monetary value returned to the palm oil industry in the form of certified emissions reduction (CER) unit. Although the industry's current CDM-related biogas business is no longer valid, it has since shed some light on its durability and

**TABLE 1. INCENTIVES FOR RENEWABLE ENERGY (RE) BUSINESS ENDEAVORS**

| Type of incentive | Description |
|---|---|
| Pioneer Status (PS) | Exemption from income tax on 100% of statutory income for 10 yr. |
| Investment Tax Allowance (ITA) | 100% of qualifying capital expenditure incurred within 5 yr, with allowance deducted against 100% of the statutory income for each year of assessment. |
| Eligible activities for PS and ITA | Companies intending to sell all the energy generated to its related companies or any other companies are eligible for:<br>(1) PS with tax exemption of 100% of statutory income for 10 yr.<br>(2) ITA of 100% for 5 yr to be offset against 100% of the statutory income.<br><br>Companies intending to generate RE for own consumption are eligible for:<br>(1) ITA of 100% for 5 yr to be offset against 100% of the statutory income.<br><br>Companies intending to sell all the energy generated to its related companies or any other companies and for its own use are eligible for:<br>(1) PS with tax exemption of 100% of statutory income for 10 yr for energy sold.<br>(2) ITA of 100% for 5 yr to be offset against 100% of the statutory income for the whole project. |
| Import duty | Imported machinery, equipment, materials, spare parts and consumables used directly in the RE generation process. |
| Sales tax exemption | Locally purchased machinery, equipment, materials, spare parts and consumables. |

practicability as potential revenue earner applicable in other voluntary carbon trading schemes. However, the additionality in earning credits for carbon trading is feared to be abolished and the monetary value might be discounted if it is intentionally made mandatory for specific requirement. In future, a more climate-friendly and politically-driven mechanism may be put forward but there is still a lack of details on how to operate sustainably (Baker and McKenzie, 2016). The National RE Policy and Action Plan puts forth a quite lucratively FiT to encourage the use of biomass energy, offering a total of RM0.47 $kWhr^{-1}$, including all additional bonuses *e.g.* use of locally manufactured gas engine, highly efficient thermal conversion, *etc*. These changes can only be realised through government's imposition of an additional 0.6% charge from the current 1.0% consumers' electricity bill, making a total of 1.6% RE fund to support this initiative.

## PALM OIL MILL EFFLUENT DISCHARGE LIMIT

POME final discharge limit is governed by the national law - 1977 Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations. The quality of the final discharge is of great concern to the public as the discharge will end up in various waterways and affect water quality. The most critical parameter of POME affecting the environment is the biological oxygen demand (BOD). The Law, previously prescribing a final discharge BOD of 100 ppm starting in 1984, revised it to 20 ppm BOD since 2006 in Sarawak and some environmentally-sensitive areas in Sabah (DOE, 2010). Sarawak was then given a 3-year grace period for full compliance; while a BOD discharge limit of 50 ppm was allowed within that period until 31 December 2019. Due to environmental awareness, Johor had followed suit and began the implementation of 20 ppm BOD in several environmentally-sensitive areas.

During palm oil milling, an abundant wastewater *i.e.* POME is generated amounting to about 65 million tonnes. Proper treatment of POME's high BOD and chemical oxygen demand (COD) will ensure acceptable levels of final discharge limits to meet POME regulations. In order to meet BOD of 100 ppm or lower, the conventional ponding systems have to be equipped with efficient tertiary treatment technology (*Figure 1*) or partially treated anaerobically for biogas production prior to tertiary polishing. If the biogas produced is captured, it will be able to mitigate GHG. In addition, methane avoidance via composting or other means can be another approach in combating biogas emissions. Ultimately, all milling by-products generated should be fully utilised to achieve a zero-discharge or circular economy (*Figure 2*) (Loh *et al*., 2019b). Through biogas capturing via AD of POME, a lower BOD level that will ease polishing process later on can be achieved in gearing towards 20 ppm BOD compliance. Examples of biogas systems developed are: MPOB-BEE biogas fermentation system (*Figure*

**TABLE 2. PERFORMANCE OF TWO BIOGAS SYSTEMS DEVELOPED (in terms of palm oil mill effluent (POME) quality and biogas characteristics)**

| Parameter | Characteristics | | | |
|---|---|---|---|---|
| | MPOB-BEE | | MPOB-SJTU-RONSER | |
| Raw POME | | | | |
| COD (ppm) | 44 000-83 000 | | 32 000-70 000 | |
| BOD (ppm) | 14 000-34 000 | | 28 000-30 000 | |
| Discharge after biodigester | | | | |
| COD (ppm) (% reduction) | 1 400-2 500 | (90-95) | 2 000-3 000 | (93.7) |
| BOD (ppm) (% reduction) | 50-500 | (90-95) | 800-1 000 | (~95) |
| Composition of biogas | | | | |
| Methane (%) | 56-64 | | 65-70 | |
| Carbon dioxide (%) | 35-41 | | 25-30 | |
| Hydrogen sulphide (ppm) | 217-1 418 | | 300-1 500 | |
| Volume of biogas ($m^3$ $m^{-3}$ POME) | 26.6-30.0 | | 21-25 | |

Note: BOD - biological oxygen demand; COD - chemical oxygen demand.

*3)* and MPOB-SJTU-RONSER zero discharge POME treatment technology (*Figure 4*). These two systems are capable of reducing 90%-95% BOD and COD (*Table 2*). If the remaining partially treated POME can be taken care of by an effective tertiary treatment system, then the POME final BOD discharge limit of 20 ppm is achievable.

## BIOGAS DEVELOPMENT

At the national level, a potential of 483 MW of power can be harnessed (*Table 3*) if all biogas (~1789 million $m^3$) emitted from 452 palm oil mills were captured in 2019. The harnessing of this amount of green energy indicates huge mitigation opportunity to lessen dependence on fossil fuels. As of December 2019, a cumulative 125 plants or ~28% of national biogas implementation (*Figure 5)* were in place having a mixed trend in biogas utilisation (Loh *et al.*, 2017; Loh *et al.*, 2019a). The captured biogas can be used in many different applications: electricity generation either for grid connection under FIT (depending on quota availability) or off-grid utilisation for downstream activities in close proximity to a palm oil mill or a palm oil refinery; biogas for co-firing or combined heat and power (CHP); biogas supplying for rural electrification and a new/emerging off-site utilisation trend if all the above are non-applicable as bio-compressed natural gas (bio-CNG).

For bio-CNG deployment, however, the investment will be heavy as an additional RM7-8 million is required to upgrade the produced biogas into high purity biomethane on top of the same amount used for gas pre-treatment, electricity generation via gas engine and grid connectivity. Bottling of upgraded pure biomethane from biogas can be used as a supplemental fuel to replace fossil fuel/oil for industrial processes or as a transportation fuel for vehicles powered by natural gas. Since October 2015, the world first commercial bio-CNG plant (*Figure 6)* from POME was operational in Malaysia at a palm oil mill situated at Sg. Tengi, Selangor (Nasrin *et al.*, 2020). It upgrades about 600 $m^3$ $hr^{-1}$ of raw biogas produced from the covered lagoon biogas plant to 400 $m^3$ $hr^{-1}$ bio-CNG which is bottled and used to substitute fossil-based natural gas for industrial uses. In future, bio-CNG business can be expanded for distribution via national gas grid pipelines for many different applications.

Currently, the uptake of biogas implementation nationally may face challenges due to: 1) limitation of quota and RE funds; 2) grid connectivity issues - high cabling cost, load demand, safety requirement and distance of substations from respective mills; 3) limited biogas utilisation track record; 4) lack of institutional/ regulatory coherence and supporting framework; 5) high overall investment cost and 6) uneasiness to change due to a decade-long comfort zone focusing on oil production. Practically, these challenges can be addressed by trapping biogas not only for grid connection but also for other on-site options *e.g.* co-firing, whichever is more feasible in the longer run. As annual biogas quota availability is based on limited RE fund and revocation of non-compliant feed-in approval holders, no assurance or priority of quota is to be affirmed; all subjected to first come, first served. Previously, minima quota was released based on RE fund availability, sectoral uptake rate and revised adjustment but starting 2018, new mechanism for quota approval has been put in place such as open bidding system.

## PALM OIL MARKET COMPETITIVENESS

Biogas from POME contains about 60%-70% methane, 30%-40% $CO_2$ and trace amount of $H_2S$ (Loh *et al.*, 2013). As methane is 28 times more potent than $CO_2$ as a GHG (IPCC, 2014), its release to the environment is not desirable. An estimated 18 million tonnes $CO_2$ eq. total GHG emissions can be mitigated annually if all palm oil mills embark on trapping the


Source: Loh *et al*. (2019b).

*Figure 2. The case of the circular palm oil economy.*

*Figure 3. MPOB-BEE highly efficient biogas fermentation system.*

*Figure 4. A zero discharge palm oil mill effluent treatment pilot plant at MPOB's Experimental Palm Oil Mill (POMTEC), Labu.*

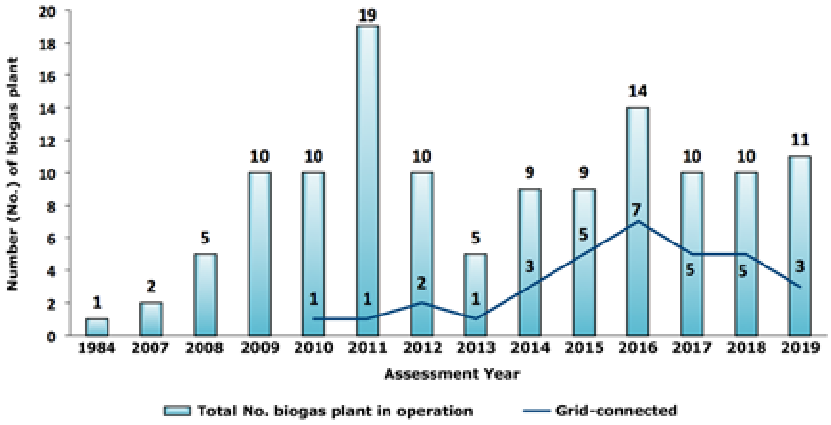
emitted biogas one way or another. However, our mapping exercise shows that about 40% of palm oil mills are not within feasible means for grid-connected electricity generation, let alone for other applications as they either are of small capacity or far from national grid.

Having said that, from the point of tightened market accessibility, capturing biogas from POME is valid for a prominent reason *i.e.* sustainability. It is seen majorly as a green initiative to strengthening palm oil or palm products competiveness in global market. It has been shown that the serial capturing of biogas in the country has now able to mitigate GHG emissions of ~5.52 million tonnes $CO_2$ eq. yearly (Loh *et al*., 2017).

It was revealed under the Third National Communication and Second Biennial Update Report (inventory year 2014) that the Malaysia's total GHG emission in 2014 was 317 626.83 Gg $CO_2$ eq. Of these, the waste sector represents only 9% in which ~55% are from POME. Methane takes 18% of the total GHG and 28% are derived from POME. This reflects that methane emissions from POME contributes to ~4.9% of the national GHG emissions (2014), and national biogas implementation contributes to ~38% in the pledged carbon intensity reduction target (*i.e.* 45%) by 2030 (INDC Malaysia, 2015).

The importance of biogas capture can be gauged from the EU Directive on the Promotion of the Use of Energy from Renewable Sources (EU RED). The EU RED stipulates that any type of biodiesel consumed must be able to meet a typical GHG savings threshold set and for palm biodiesel, the value is 36% (for no land use change) and 62% (for methane capture). The GHG savings evidenced by Choo *et al*. (2011) show 51% and 66%, respectively, when palm oil is used to produce palm biodiesel. In term of tonne $CO_2$ eq. per tonne refined oil, palm oil (1.11) shows much lower GHG emissions compared to rapeseed (1.35) and soyabean (1.70) oils (Mortimer *et al*., 2010). Moreover, if biogas is captured at palm oil mills, a much lower GHG emissions (0.63) can be achieved.

On top of that, biogas trapping can also complement the sustainable palm oil certification internationally endorsed via several schemes *e.g.* the Roundtable on




Source: Loh *et al*. (2019a).

*Figure 5. Progress and trend of biogas capture and utilisation (2007-2019) for the Malaysian palm oil industry.*


Source: Nasrin *et al.* (2020).

*Figure 6. World first bio-CNG plant in Malaysia (MPOB-Felda Palm Industries Sdn. Bhd. - Sime Darby Offshore Engineering Sdn. Bhd.).*

CPO, the requirement to have biogas trapping facilities at palm oil mill premises is market-driven based on country level assessment, company policy, consumer preference, *etc*. At national level through biogas co-firing, the particulate matter emissions during the palm oil milling process can be much reduced (Nasrin *et al*., 2019) to facilitate compliance with the newly regulated Environment Quality Act (Clean Air) Regulation starting 2014 at all palm oil mills (DOE, 2014).

## CONCLUSION

The environmental aspects of the Malaysian palm oil business activities should be emphasised rather than just jeopardising profitability. Through more than a decade-long progressive development and to stay competitive and relevant, the oil palm industry must be responsive to the new aspect of holistic POME treatment alongside biogas trapping be it a lucrative business or merely for environmental protection. No doubt there is saying that no pain no gain, but if pain strikes without us working on it, it will be too late to rectify the potential damages caused. The advantages of biogas

**TABLE 3. ENERGY POTENTIAL OF BIOGAS FROM PALM OIL MILL EFFLUENT (POME) IN 2019**

| Material | Production rate | Quantity |
|---|---|---|
| Fresh fruit bunches (FFB) | - | 98.28 million tonnes |
| POME | 0.65 $m^3$ $t^{-1}$ FFB | 63.88 million $m^3$ |
| Biogas[a] | 28 $m^3$ $m^{-3}$ of effluent | 1789 million $m^3$ |
| Total heat value | 1 789 x 20 million MJ<br>= 35 774 million MJ | 35 774 million MJ<br>= 9.94 million MWh[b] |
| Power output | 35% of heat input | 9.94 million MWh x 35%<br>= 3.478 million MWh |
| Power plant size | Plant operates 300 day $yr^{-1}$ = 7200 hr $yr^{-1}$ | 3 478 020/7200<br>= 483 MW |

Note: [a]Calorific value = 20 MJ $m^{-3}$, STP.
[b]1 MJ = 1/3600 MWh.

Sustainable Palm Oil (RSPO) and International Sustainability and Carbon Certification (ISCC), besides those adopted at country level *e.g.* the Malaysian Sustainable Palm Oil (MSPO) *vs*. Indonesian Sustainable Palm Oi (ISPO) Certification and MPOB Codes of Practice (CoP). Through these certification schemes sourcing for sustainable trapping, if fully optimised, would be multiplied manifold through innovative undertakings. Most importantly, the industry that is blessed with so much of natural resources must show intimate leadership by championing this renewable area for bioeconomy development.

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