From Waste to Wealth

Ir. Hor Kok Luen

Malaysia has abundant waste and biomass resources generated from agriculture-based industries, particularly Crude Palm Oil (CPO). The decomposition of agro-industry waste releases biogas via microbiology processes through the methanogensis stage after the hydrolysis and acidification stage. The biogas, mainly methane, is considered Green House Gas (GHG).

Due to environmental concerns over the GHG emission effect, the proactive action, besides the compliances concerned from the industry players, is to treasure biogas as an abundant source of renewable energy that is untapped but commercially valuable as it's easily available.

This proactive move is supported by nations as a way to minimise our dependence on the use of fossil fuel. We still depend largely on conventional energy sources (fossil fuels such as oil, natural gas and coal) but in the next few decades, it is hoped that we will gradually become less dependent on them.

The technology for harnessing green energy is not new. It has been continuously developed over the last few decades and has grown in intensity in Malaysia and all over the world.

To enhance the tapping of green energy from biomass and biogas in industries, team work and collaboration between the various parties concerned – governing bodies, industry players and technology providers – are crucial.

What are the matured engineering approaches that can be adopted in this context? What would be the expected challenges, technically and commercially?

BIOGAS GENERATION

Any industry that produces large amounts of organic waste, is a candidate for biogas production. A standard biogas production system begins with large anaerobic digesting tanks/ponds where the organic waste is converted into biogas.

There is the presence of naturally occurring bacteria, mainly Thermophylic and Mesophyllic types. Given the right temperature and feeding environments, the bacteria will thrive and propagate.

The palm oil based liquid waste, mainly organic loading containing oil and shredded waste, will increase the surface area available to microbes in the digesters and so increase the speed of digestion.

The anaerobic digestion process takes place in an airtight containment (O_2 depleted) which will be the digester. The first stage of chemical reaction Anaerobic Digester (AD) is hydrolysis, where complex organic molecules are broken down into simple sugars, amino acids and fatty acids with the addition of hydroxyl groups.

There are many configurations of Anaerobic Digesters and these can run at different target temperatures; the most common are Mesophillic (35°C) or Thermophilic (50°C). There are different populations of anaerobic microbes that thrive in these temperature zones. Digesters can combine all the main process chemistry steps (hydrolysis, acidification, acetogenisis, methanogenis) either in a single process reactor tank or in two separate reactor tanks. The separation of digestion phases allows for additional process control but it does incur additional capital costs.

This is followed by three biological processes:

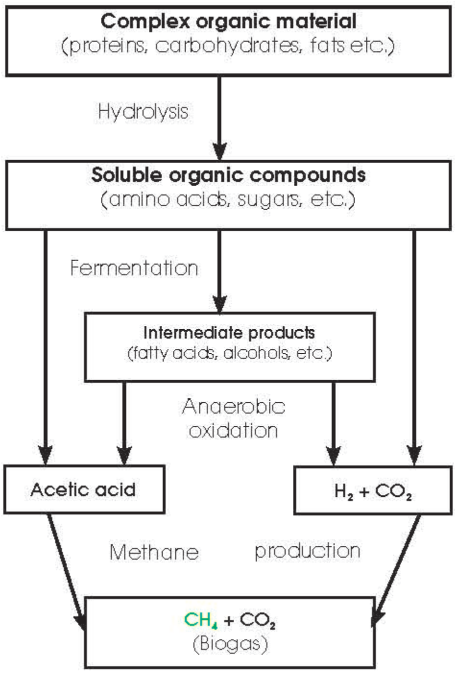
1. **Acidogenesis** – further breaking down by acidogenic bacteria by into simpler molecules, volatile fatty acids (VFAs) occurs, producing ammonia, CO_2 and hydrogen sulfide as byproducts.
2. **Acetogenesis** – the simple molecules from acidogenesis are further digested by bacteria called acetogens to produce CO2, hydrogen and mainly acetic acid.
3. **Methanogenesis** – methane, CO_2 and water are produced by bacteria called methanogens.

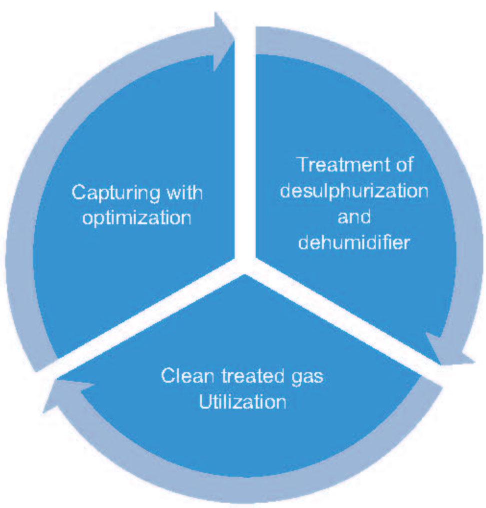
The pH levels are kept between 6.5 and 8.0 and the temperature between 30°C and 60°C, in order to maximise digestion process.

A large amount of the climate impact of the emission of methane can be mitigated by capturing the gas and using it to fuel the power plant; biogas technology has been used successfully for decades and can produce renewable electicity at a cost that's competitive with traditional fuels.

THE BIOGAS PROCESS

Under anaerobic conditions, organic material is decomposed by microorganisms in a number of steps to get the final products, methane and carbon dioxide.





Full Scope of Biogas Project

SUSTAINABLE ENERGY DEVELOPMENT AUTHORITY (SEDA) MALAYSIA

The enforcement of the Renewable Energy Act 2011 (Act 725) on 1 December, 2011, enabled the implementation of Feed-in-Tariff (FIT), paving the way for a sustainable Renewable Energy (RE) growth trajectory in Malaysia. Renewable Energy includes solar photovoltaic, small hydro, biomass and biogas.

All RE resources show promising development as can be seen from the number of projects which have benefited from FIT.

As the agency responsible for the facilitation of RE growth, SEDA Malaysia is playing its role to ensure that installations, especially those under the FIT mechanism, meet and comply with international standards in terms of quality, reliability and safety as this will indirectly impact the performance of the biogas power plants.

COMPARISON OF BIOGAS ENERGY (EQUIVALENT) WITH OTHER AVAILABLE FUEL

At 1 m^3 biogas of CH_4 at 60% concentration........
Low heating value (LHV) = 21474 KJ/NM³

Replace biomass (PKS and Fibre) with biogas

- 1 m^3 of biogas can replace 1.4 kg of palm kernel shell (PKS).

Replace diesel usage with biogas

- 1 m^3 of biogas can replace 0.60 litres of diesel.

Generate electricity with biogas

- 1 m^3 of biogas can generate 1.5-2.0 KWH of electricity.

Replace gasoline usage with biogas

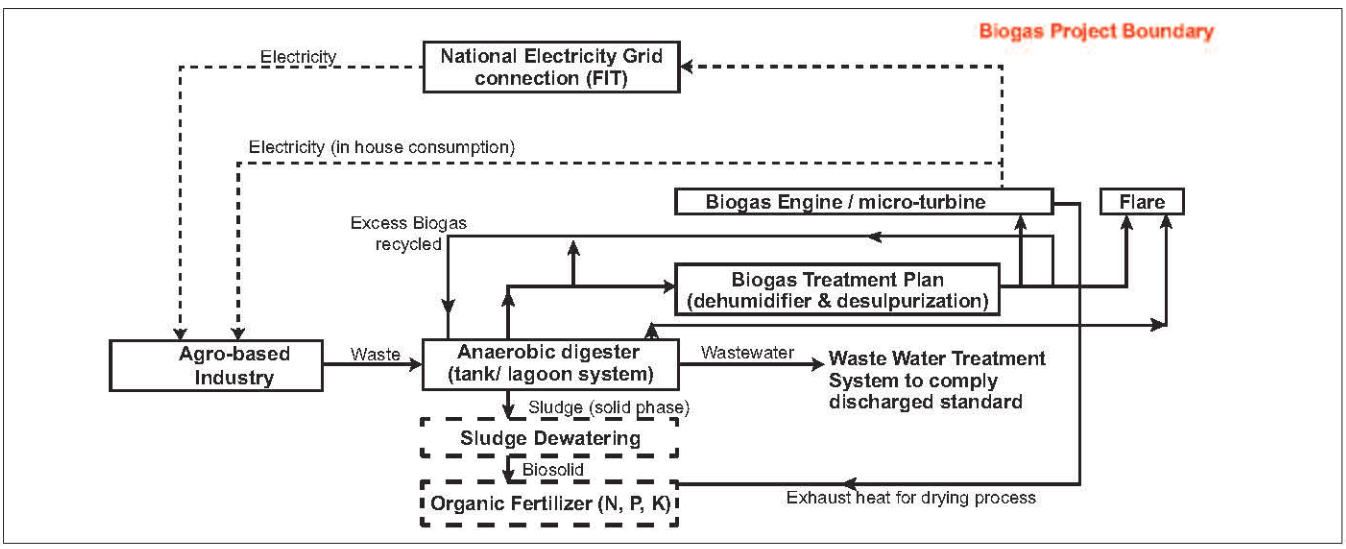
- 1 m^3 of biogas can replace 0.67 litres of gasoline.

Replace wood usage with biogas

- 1 m^3 of biogas can replace 1.5kg of wood.

Replace LPG gas usage with biogas

- 1 m^3 of biogas can replace 0.46kg of LPG (Liquid Petroleum Gas).



Typical biogas project boundary

FROM BIOGAS TO BIOMETHANE

Biomethane is produced from biogas through an Upgrading Process with water wash technology involving a purification process that essentially removes all Hydrogen Sulphides (H_2S), Carbon Dioxide (CO_2) and Siloxanes.

Biogas has actually gained increasing positive response and popularity in developed countries as the leading green fuel alternative. Being renewable based and without conventional fossil fuel pollutants, biomethane is being utilised increasingly by international institutions of alternative fuel, now and in the future. Malaysia is in the correct time zone currently to develop and enlarge the utilisation rate nationwide and so acquire a greener image in the global market.

Biogas (Typically)	→	Biogas (Achievable)
CH_4: ~60%		CH_4: >96%
CO_2: ~39%		CO_2: ~1%
N_2+O_2: <1%		O_2: <0.4%
H_2S: 50-5000ppm		H_2S: <1ppm
H_20: Saturated		H_20: <1ppm
Siloxanes: Trace		Siloxanes: <1ppm

Chemically, biomethane is no different from natural gas, thus making it the ideal replacement for use in Natural Gas Vehicles (NGV). Obviously its commercial value is remarkable besides it being environment-friendly.

BIOGAS CAPTURING TECHNIQUES

There are generally 2 types of Anaeroboic Digesters (AD): Tank System and Lagoon System.

1. Tank System (Tank Farm)

a) Concrete is commonly used to make the digester tanks as it can store and retain heat uniformly. The tanks can be cylindrical or oblong in shape. It can be constructed on an in-situ basis or prefabricated in a workshop, shipped to the project site and assembled there. Sometimes, a coating is applied to the inner wall of the tank, especially in the corrosive gas/water interface zone, to ensure long-term durability.

b) Steel is another material that's also commonly used to make digester tanks. Steel tanks can be erected in bolted basis together with panels or as welded steel panels. The steel can be either stainless steel or steel coated with epoxy paint, a common industrial practice. The material selection is the key part to ensure durability and resistance to corrosion.

Palm Oil Mill Effluent (POME) biogas capturing plant

2. Lagoon System (Soil Lagoon or Engineered Lagoon)

This anaerobic system is built in a rectangular shape and covered with High Density Polyethylene (HDPE) plastic sheet or PVC and used as a container for the biogas generated. The sheets may cover the whole lagoon or only the parts generating methane. The system also increases contact area of bacteria sludge with waste water and develops a system to pull sludge with pipes. In other words, the lagoon houses the methanogenesis process and the lagoon top section is the gas storage buffer zone.

Raw Biogas Composition

COMPOSITIONS	TYPICAL	(UAC)
Methane	50-60%	60-72%
CO_2	25-40%	25-35%
Water	0-5%	0-3%
N_2	0.01-2%	0.01%-0.5%
O_2	0.01-0.6%	0.01-0.2%
H_2	0.1%	-
H_2S	3000ppm	8000ppm

FACTORS AND PARAMETERS AFFECTING BIOGAS GENERATION

√ The amount of waste effluent (m³/day).
√ The amount of Chemical Oxygen Demand (COD).
√ The COD removal rate of the design system.
√ Methane-COD equivalent (kg-CH_4/kg-COD).
√ Methane gas density (kg/Nm³).
√ Methane gas concentration.
√ Ambient Biogas temperature.

OPTIMISATION OF BIOGAS SYSTEM

It is crucial to have the process flow running in optimum condition as optimisation will eventually lead to sustainability. Most importantly, all operating factors highlighted in this paper must be in optimal mode, regardless of time, day or place. By having zero/minimum fluctuations on the key operating factors and parameters as highlighted above, the quality and quantity of the biogas generated can be secured and sustained.

TECHNICAL & COMMERCIAL CHALLENGES

The expected challenges in biogas projects can be basically summarised, but not limited to, as below:

Commercial Challenge No. 1

High capital investment, especially the fluctuation of global market currency

√ Overall trading currency is in USD.
√ Capital investment in millions of ringgit.
√ Duration of completion at least 12-18 calendar months.

Commercial Challenge No. 2

Strategic location of the plant: Ensure FIT is available

√ Strategic location, meaning FIT is necessary.
√ Authorities involved: Energy Commission (ST), SEDA, Tenaga National Berhad (TNB) and others.
√ Need to carry out Power System Study (PSS) before a project can be claimed to be overall feasible.
√ Need to purchase quota earlier from the authority (SEDA, in this context).
√ Ensure to purchase quota with the best rate (basic rate + others bonus rates).
√ Bonus rates offered by SEDA are inclusive but not limited to G1 (Agricultural Waste), G2 (Electrical Efficiency) and G3 (Local Assembly Status).

Commercial Challenge No. 3

Practical business strategy: Ensure that power generated can be utilised internally, besides the FIT purpose.

√ Ensure the company is able to consume the power generated (Palm Oil Mill, downstream plants and staff quarters).
√ The power generated can be used for the entire factory and complex.
√ No wastage concerns.
√ Overall, the key consideration is on the demand and supply of electrical power.

Commercial Challenge No. 4

To get the support and approval of Malaysia Industrial Development Authority (MIDA) on tax deduction/exemption on green energy development

√ Biogas energy is classified as Green and Renewable Energy.
√ MIDA giving tax incentives to green technology providers and end users.
√ Need for comprehensive documentation before submitting to apply.

Technical Challenge No. 1

Good feed stocks on the raw materials: Consistency & Regularity

Overall layout of Biogas Capturing & Treatment Plant

- √ Raw materials, in this context, is Fresh Fruit Bunch (FFB) and Palm Oil Mill Effluent (POME).
- √ Supply must be consistent and sufficient (daily, monthly and annually).
- √ Able to purchase FFB and produce POME consistently.
- √ Have a buffer zone on POME storage.
- √ Good milling and processing efficiency.
- √ Good marketing strategy to obtain raw materials.

Technical Challenge No. 2

Management of bio-solids formed during the biogas capturing process

- √ Solid handling (do not underestimate).
- √ Solid generated should be handled and well managed. Prevent the occurence of any potential environmental issue.
- √ Good practice = disposal (manageable). Poor practice = dumping (uncontrollable).
- √ Accumulation of solids can affect biogas plant performance by reducing the hydraulic retention time.
- √ Convert to value added products (N,P,K).

Technical Challenge No. 3

Footprint and location for the biogas project

- √ Space and land area concern.
- √ Control the footprint.
- √ In the vicinity of palm oil mill = minimum cost on handling and transportation.
- √ Power supply and water supply.
- √ Road and transport = accessibility.

Technical Challenge No. 4

Technically competent personnel must be in the operating team

- √ Well-trained personnel.
- √ Competency in POME treatment handling.
- √ Mentally, technically and physically prepared.
- √ Not only can generate but also able to manage (control).
- √ Safety concern.
- √ Power management.

Technical Challenge No. 5

There are numerous tests and inspections (initial and regular) involved

- √ SEDA ATPA test.
- √ TNB safety test-Islanded Test and loss of main.
- √ TNB PQ Test.
- √ TNB availability test.
- √ In-house test-all aspects.
- √ Instrument calibration and testing.
- √ JKKP plant annual inspection.

CONCLUSION

If we want to make the world a greener place and to enhance the degree of tapping on green energy (biogas in this context) from agro-industry waste, it is crucial to have team work and collaborative efforts of the various parties (governing bodies, industry players and technology providers) involved.

To be able to transform and diversify to reach sustainability stage, industry players must realign their direction, both technically and commercially, and move forward. The initiatives and proactive behaviours of industry players are crucial to turn positive transformation into reality. Remember, the planet is owned by all living beings. ■

Author's Biodata

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