Biogas as a Means to Reduce Carbon Footprint and Protect the Environment: A Comparative Legal Analysis between Malaysia and Thailand

Hashif Aizad Hasrudi[1], Muhammad Qurtubi Kamruldzaman[2], Muhammad Thaqif Rusyaidi Tarmizi[3], Raja Sara Nabila Raja Shaiffulizam[4],Yuliana Ashikin Yusaini[5], Zahid Zulkifli[6], Mohd Haris Abdul Rani[7]*

[1]Malaysian Communications and Multimedia Commission (MCMC), Malaysia

[2]Messrs Ahmad Danial Iswatt & Luqman, Malaysia

[3]Messrs. Afdhilani, Malaysia

[4]Messrs. Sidek Teoh Wong & Dennis, Malaysia

[5]Messrs Haris Ibrahim Kandiah Partnership, Malaysia

[6]Nazmi Zaini Chambers, Malaysia

[7]Faculty of Law, Universiti Teknologi MARA, Malaysia.

***Corresponding Author**

DOI: https://dx.doi.org/10.47772/IJRISS.2025.91100600

Received: 23 November 2025; Accepted: 30 November 2025; Published: 26 December 2025

ABSTRACT

With increased international efforts to combat climate change, many countries have initiated a strategic shift toward alternative energy sources, such as biogas, in an effort to reduce carbon emissions and enhance environmental protection. However, due to the lack of a coordinated international strategy, a disjointed governance framework guides biogas development, resulting in significant discrepancies in its national implementation. The current study presents a comparative analysis of the strategies adopted by Thailand and Malaysia in utilising biogas as a renewable source of energy, as both countries share similar capacities for biogas production. It was found that Thailand has developed a more proactive system of governance and a broad range of regulatory mechanisms for biomass development compared with Malaysia. This is demonstrated by the consistent application of Feed-in Tariff incentives in Thailand, sustained investment support, and active participation in international mechanisms that support renewable energy, which together present a more robust landscape for biogas development.

Keywords: Biogas; Carbon Footprint; Climate Change; Thailand & Malaysia, Energy Policy

INTRODUCTION

The reliance on industrialisation towards fossil fuels contributes to the degradation of our environment. (Mgbemene et al., 2019). Greenhouse gas (GHG) emitted from the production of such energy affects our environment. (Denchak, 2019). Not to mention other conventional energy sources that produce carbon footprint contribute to the deterioration of our environment. By understanding the relationship between carbon footprint and climate change, we can find a solution to protect the environment. According to LaMeaux (2021), scientific research by the United States Energy Information Administration provides ample evidence that the carbon footprint emitted daily contributes to the increase in Earth's temperature.

The world is now keen on the search for clean and renewable energy sources, as it brings a positive impact to the environment. Since the 19th century, biogas has been widely used as one of the alternatives for energy production. Being naturally produced in an anaerobic environment, it played a role in reducing waste energy production.

Thailand has been using biogas as one of its renewable energy sources due to the abundance of agricultural waste (Chaiprasert, 2011). Besides that, Tonrangklang et al. (2017) also mentioned that in Thailand, there are more than 1700 biogas plants supported by the Ministry of Energy and could help to generate millions of joules of energy per year. Therefore, in this paper, the successful application of biogas in Thailand might help to pave the way for the introduction of biogas in Malaysia as one of the renewable energy sources.

LITERATURE REVIEW

Biogas as a Means to Reduce Carbon Footprint

According to Zhu et al. (2019), the enhanced biogas, called biomethane, in which carbon dioxide and other impurities have been removed, has similar chemical characteristics to fossil gas and can be supplied right into existing gas networks or distributed to gas stations as a vehicle fuel. This can help minimise the spread of greenhouse gases into the air.

Tonrangkang, Therdyothin and Preechawuttipong (2017) asserted that in Thailand, the government has been persistently advocating for the production of biogas, which includes the financial cost and technical consultants, for over two decades. This encompasses Thailand's energy policies and plans that foster the utilisation of biogas to produce biomethane as a substitute for natural gas vehicles. Cassava starch has the highest potential for biomethane production in Thailand. Besides that, the booming industry of ethanol in Thailand also helps to catalyse the production of biomethane due to the power of ethanol to produce biomethane.

Malaysia is one of the largest producers of palm oil. According to Hoo et al. (2017), palm oil mill effluent (POME), agro-based industries and farming industries have been determined to have potential for biogas. Also, since Malaysia is a heaven for palm oil, it has been found that over 500 kilotons of biomethane can be produced annually if all the POME is processed in anaerobic methods.

Life Cycle Assessment

Life cycle assessment (LCA) is a standardised technique that can be utilised to evaluate environmental responsibilities associated with goods, methods or amenities by determining the energy, materials utilised, and discharge released to the atmosphere (International Organisation for Standardisation, 2006; U.S. Environmental Protection Agency, 2006). This LCA method has been implemented globally for years, and it has dramatically enhanced in the past few years (Abagnato et al., 2024; Rashid et al., 2023).

Nevertheless, with regard to LCA in Malaysia, Aziz et al. (2019a; Aziz & Hanafiah, 2019b; Aziz et al., 2019c) also claimed that this method is still novel and it is still not yet fully developed in Malaysia. Lamnatou et al. (2019), however, noted that the conceptual framework of environmental sustainability assessment of the biogas process that utilised LCA has been suggested to maximise the longevity of the biogas stockpile. This conceptual framework can be made as a parameter for the associated parties with an interest in the project and administrators to advance the quality and maximise the sustainability of biogas production in Malaysia, and also to advocate for biogas as a safe, clean, and stable energy (Hafizan et al., 2020).

In Malaysia, LCA is mostly done by SIRIM Berhad and the Malaysian Palm Oil Board. (MPOB). A number of fields have been included in the LCA research, which include the management of waste, agricultural business, petroleum, and palm oil. Research by Nur Izzah, Marlia and Yasreen (2019) found that there are six types of substrates that provide the chances for biogas production in Malaysia. Moreover, according to Foong, Chong and Ng (2021), newer analyses were conducted pertaining to the production of biogas that is outsourced from the anaerobic breaking down of a palm oil mill effluent with the goal to put emphasis on the practicability of LCA in the production of biogas.

The analyses also include the chances and obstacles based on the Malaysian point of view (Foong, Chong, & Ng, 2021). In spite of that, Nur Izzah et al. (2020) also asserted that the government has not implemented strict regulations with regard to the establishment of and the use of biogas plants, even though several green policies have been made. Even though biogas in Malaysia is still at the embryonic phase, there is a high likelihood of successfully achieving the sustainable development of biogas (Wan Syakirah et al., 2019).

However, in contrast with Malaysia, despite Thailand being classified as the leading producer of biogas in Asia, there is a lack of certainty in LCA studies for biogas production in Thailand. This is because of the inadequacy of information in its LCA databases. The biogas studies in Thailand have also not been done on LCA. The information that is available in Thailand's LCA records may not exactly reflect the amount that has been researched because of the territorial or geographical location in Thailand. Despite the fact that the new Thai National Life Cycle Inventory database was formed, there is a lack of information pertaining to biogas production in Thailand in the database. (Yacout et al., 2018).

Feed-In Tariff

Based on the report by Germany's Federal Ministry for Economic Affairs and Energy (2015), in 2014, Thailand implemented the Feed-In Tariff bidding system (FiT), replacing the old "adder scheme", which is also called Fit-in-Premium. FiT rate is made of FIT(F), an amount that is unchanged for the entire support duration of 20 years and FIT(V), a segment that changes based on the inflation rate. Moreover, premiums are awarded with the goal of the utilisation of certain fuels or projects located in the three provinces at the far south of Thailand. Following this scheme, the sum base of FIT, which is the addition of FIT(F) and FIT (V), as of now, equals THB 3.76 (MYR 0.48) in relation to biogas from wastewater and waste product and THB 5.34 (MYR 0.69) with regard to biogas from energy crops.

Mekhilef et al. (2014) demonstrated that in Malaysia, the FiT, which is governed by the Sustainable Energy Development Authority (SEDA), was developed to be consistent with the National Renewable Energy and Action Plan 2010. This FiT proposes the need for legislative guides to expand the renewable energy share in Malaysian biogas. However, as compared to Thailand, Malaysian FiT on biogas is not as concise. This is due to the limited quota for electricity feed-in and location constraints, hence not every biogas produced can be benefited from (Poh, Haslenda & Wai, 2018). Besides that, FiT in Malaysia covers a period of 16 years for biogas (Timo, 2020).

RESEARCH METHODOLOGY

This study aims to promote the use of Biogas in order to reduce carbon footprint and protect the environment in
Malaysia. Hence, the study will then apply a qualitative method to compare with the Energy Policy of Thailand. This means that this study will analyse published documents in order to assess the success of Malaysia's present energy policy. This approach is known as library research. Accordingly, our qualitative method consists of two sorts of materials: main sources, such as Malaysian and Thai energy policies, and secondary sources, such as papers and journals from the internet.

Regulatory Framework

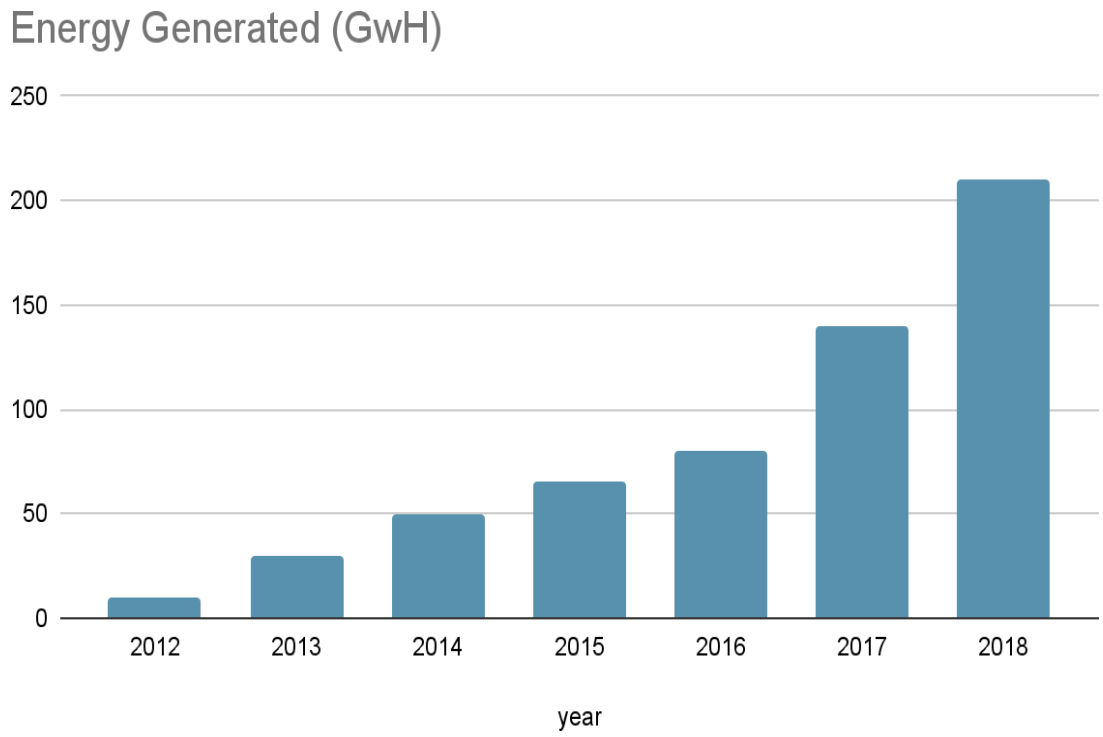
The main regulatory framework for regulating renewable energy, such as biogas, can be seen through the Feed-in-Tariff (FiT), which began on 1 December 2011. Basically, energy utilities are required to buy renewable energy from producers at a set price under the Feed-in Tariff mechanism. The application of FiT in Malaysia would allow for the emergence of new enterprises, the creation of new employment, and the development of new growth areas, paving the way for us to become the region's leader in green technology and low-carbon economic growth.

As mentioned before, LCA is utilised in evaluating environmental responsibilities as well as maximising the sustainability of biogas stockpiles. Aziz et al. (2020), in their research, found that LCA studies are conducted by the Malaysian Palm Oil Board (MPOB) and Standard and Industrial Research Institute of Malaysia Berhad (SIRIM). It seems that areas such as petroleum, agro-industry and palm oil environmental impact and assessment are evaluated through LCA. Recent research on biogas production from palm oil mill waste anaerobic digestion (AD) has been carried out to show the effectiveness of the LCA approach in biogas production, as well as the opportunities and restrictions from a Malaysian context.

Even with different green policies that have been devised or implemented, the government has not issued any specific restrictions regarding the installation and use of biogas plants. Even though biogas generation is still

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XI November 2025

in its infancy in Malaysia, it has a lot of potential in terms of achieving long-term development. Thus, it is critical to evaluate the system's environmental performance in order to ensure and improve its long-term viability. The government and other stakeholders will benefit from a good guideline, such as an LCA-based conceptual framework, which will enable better judgments about how to improve biogas production's environmental performance.



(Figure 1. Graph Of Energy Output of Biogas in Malaysia. Adapted from Jain, S. (2018). World Biogas Association Market Report)

Evidently from Figure 1, the schemes stipulated in the FiT and LCA were regarded as progressively expanded as there has been a gradual increase of energy output in the biogas industry; however, the potential in maximising the biogas output has not yet been achieved. Abdeshahian et al. (2016), in their article, contended that the poultry sector in Peninsular Malaysia has the biggest potential for biogas evolution from manure, with a biogas production potential of 2652.80 million m3 yr1, followed by Sarawak and Sabah, with biogas generation potentials of 440.99 and 172.26 million m3 yr1, respectively. But still, in the year 2016, there was less than 100 GWh of energy generated from the biogas industry. It was evidenced through the failure in achieving the potential results that was due to the failure of the biogas sector in optimising our own natural resource supply, as the biogas supplies were only taken from palm oil mill effluent.

However, as outlined above, it was revealed that there is enough supply of biogas that may meet the large-scale energy output, as in Malaysia, other organic resources from the farm animal waste could be taken as well, as we have a large scale of it in Peninsular Malaysia, including Sabah and Sarawak.

Further, in reference to Wong et al. (2015), it has been provided that the present Malaysian regulatory framework has failed to provide incentives towards the biomass or biogas industry players. Given that biogas production involves a lot of investment costs, biogas industry players are indeed struggling with financial difficulties. This has indirectly shown that the FiT system or the LCA have insufficiently helped the biogas industry players in venturing into this industry, making the growth rate less efficient. This is because it is the responsibility of the government to create a good business environment so that it can increase participation by producers, which will ensure the sustainable expansion of biogas processing. On top of that, the lack of support from the government and the relevant authorities towards the RE technology adoption in the current market, particularly in the biogas industry, has also resulted in a slower growth of biogas plant development in Malaysia. This is where the government framework should come in with more viable financing schemes, which later could support the industry player to adopt appropriate RE technology.

Without a doubt, Malaysia's regulatory framework in promoting the usage of biogas energy as a way of reducing carbon footprint and transitioning towards renewable energy is still not sufficient, as it has limited incentives and funding to support the high cost of initial investment in biomass energy production.

Therefore, the rationale in studying policy making and ideas from other countries' regulatory frameworks should also be considered for developing Malaysia's regulatory framework so that the country can realise its full biogas potential, which will help in preventing carbon footprint and provide protection for the environment in the future.

Thailand's biogas energy promotion policy entails a proactive plan to increase investment in the construction of industrial biogas. According to Aziz et al. (2020), since 2005, Thailand's Board of Investment (BOI), which is part of the Ministry of Industry, has given the highest bonus to a company that produces biogas from trash. This clearly proves how serious and determined Thailand is in investing in the biogas industry. Moreover, Thailand's government has also begun a strategy to improve the percentage of electricity generated from biogas. The measure increased the price of electricity generated from biogas by 0.30 Baht/kWh (0-01 US$/kWh) for a period of seven years from the date of purchase.

Another issue that compelled factories to seriously explore biogas production investment is environmental law enforcement. Increased investment in biogas generation has resulted from public and private sector measures and policies to boost investment and technical development.

FINDINGS & DISCUSSION

Relationship between Biogas Energy and Carbon Footprint

Approximately, biogas consists of 50%-70% methane (CH4), and around 30%-40% carbon dioxide (CO2), and the rest are other gases. According to Budzianowski & Postawa (2016), biogas can reduce carbon footprint. Overall, a variety of techniques can be adopted for biogas that will significantly influence reducing the CO2 footprint of biogas-based renewable energy. Due to the techniques, GHG can be reduced, hence also protecting the environment.

There are ways to reduce the amount of CO2 that is emitted into the atmosphere. As an example, the transportation industry emits a lot of CO2, and there are not many alternative technologies that can compete economically with fossil fuel usage. It is possible to reduce CO2 emissions by up to 84% by replacing fossil fuels with biogas. All of these biogas transportation applications rely significantly on local energy systems in order to reduce CO2 emissions. It is a policy issue since it necessitates regional studies at the national energy system scale for various biogas production and usage options. Using the best end-use choices helps to reduce the CO2 footprint.

In the article of the same author, they split the CO2 footprint reduction mechanism into three phases namely biomass generation, biomass-to-biogas conversion, and biogas end usage For a biomass production phase, the following solutions have been discussed: (i) soil organic carbon (SOC) accumulated where the CO2 burden decreased in the agro-biogas supply chain through cropping rotation, and also organic fertilisation also takes the place of CO2-intensive chemical fertilisation (ii) accumulating SOC via digestate based organic fertilisation as biogas-based cropping systems with biogas residues that are returned to the field have a great deal of potential to lower CO2 emissions, and (iii) when no production phase, waste is being used like manure, crop residues, and sewage sludge which benefit from biogas-based systems' multi-objective function. It gives an added advantage when it not only provides energy but also complements the system on waste management.

The following are some of the biomass-to-biogas conversion solutions: (i) increasing carbon conversion efficiency by pre-treatment of substrates that may improve access of microbes or by applying process design and control by optimising process performance, (ii) increasing AD selectivity towards CH4 by H2 injection to the AD, (iii) enriching process streams in CO2, (iv) recycling captured CO2, (v) enhancing biohydrogen generation from AD, where biomass, initially processed for biohydrogen generation, is further processed through conventional AD to yield CH4-rich biogas, and using dark fermentation, the most effective biohydrogen production method that can be easily integrated with conventional AD to create a hybrid

biorefinery process, and (vi) optimising plant maintenance by flaring biogas during plant outages, shutting the digestate storage tank with residual biogas collection, lowering internal energy usage and supplying it from renewable electricity or biofuels, and eliminating methane leaks in the plant. Other than that, solutions analysed for a biogas end-use phase include applying low-carbon biofuels and applying low-carbon electricity and heat.

The Comparison between Malaysia and Thailand

Looking at Thailand, since 2014, they have had a Carbon Footprint Reduction (CFR) label developed by the National Metal and Materials Technology Centre (MTEC) or usually known as "global warming reduction label", attached to any products that have actually, throughout a certain time, reduced their carbon footprint based on the calculation of their product lifecycle. It is crucial to consider the calculation to trace the carbon footprint produced, and it needs a thorough assessment for it to really make significant changes in our environment. The assessment of CFR has been made thoroughly as it was made based on a few factors, such as the product life cycle, including how the raw material is acquired, transportation and distribution of the product, production, usage and disposal. Two ways that it can be labelled were first, if the products achieve a reduction of 2% or more compared to their base year's carbon footprint. Even if it is just a small percentage, if there are a lot of products that can be labelled so, then it would give a significant impact to the country cumulatively. Another way is through confirmation of a benchmark threshold of carbon footprint set by the Thailand Greenhouse Gas Management Organisation (TGO) for a certain product category.

On top of the approach, active participation from Thailand in the Clean Development Mechanism (CDM) through an international level approach gave a good opportunity to utilise the biogas, as most of the registered CDM projects are based on it, over 50% in order to replace fossil fuel as an alternative to generate electricity and heat. Policies such as Partnership for Market Readiness (PMR) and Forest Carbon Partnership Facility (FCPF) had a huge impact on Thailand to boost and explore their future international and domestic market mechanisms to reduce GHG emissions, following a model developed by the World Bank Group. These policies that Thailand has are living evidence that the government is ready to explore and accept other types of energy, like biogas, to combat climate change and reduce carbon footprint.

Compared to Malaysia, despite having LCA studies that were governed by the MPOB and SIRIM, we are still lacking in governance to have biogas as a proper means to reduce the carbon footprint, when there are no strict regulations ever provided by the government. Even though Malaysia has a variety of green policies that have been introduced and ratified, it does not help the country to utilise biogas energy, even when it has been scientifically proven that it could highlight the feasibility of the LCA in producing biogas when there are no proper regulations. A proper governance for the utilisation of biogas still did not exist even in the year 2020, as it is still unregulated, which shows how far Malaysia is ready to accept biogas energy as a renewable energy source, yet it is crucial since long-term energy security and environmental protection could be improved a lot through biogas.

CONCLUSION

This paper shows that biogas energy is a good option for a country that has such a huge amount of waste that can be found at a landfill, which contains methane, and could be converted into biogas through the natural anaerobic process as a means to overcome climate change. It has been well proven in reducing GHG emissions through proper regulation that countries like Thailand have implemented. A significant approach should be taken by Malaysia if we want to truly contribute to combating climate change by reducing the carbon footprint and ideally helping as much as other nations have contributed. As a country that has a huge landfill that becomes an eyesore to the public, Malaysia could take advantage of producing biogas energy. It is unfortunate that this country is still far behind in terms of regulations related to biogas, while it could be far better if it were supported through strict governance. Hence, more research on biogas energy should have been done in order to push the government to set a proper law or regulation, as it could give a lot more advantage to the country by looking at its potential currently to mitigate climate change.

ACKNOWLEDGEMENT

This publication stems from a group project undertaken by students of the Faculty of Law, Universiti Teknologi MARA (UiTM), and we gratefully acknowledge their collective effort, research commitment and dedication in developing the foundational analysis that shaped this work. We also extend our appreciation to the Faculty of Law, UiTM, for providing an enriching academic environment that fosters rigorous inquiry and meaningful engagement with real-world industrial relations issues. Finally, we acknowledge the valuable industrial linkages supporting this publication, particularly the contribution of A. Razak & Co. PLT and its Managing Partner, Dato' Abd Razak, in the publication of this article.

REFERENCES

1. Abagnato, S., Rigamonti, L., & Grosso, M. (2024). Life cycle assessment applications to reuse, recycling and circular practices for textiles: A review. Waste Management, 182, 74–90. https://doi.org/10.1016/j.wasman.2024.04.016
2. Abdeshahian, P., Lim, J. S., Ho, W. S., Hashim, H., & Lee, C. T. (2016). Potential of biogas production from farm animal waste in Malaysia. Renewable and Sustainable Energy Reviews, 60, 714-723. https://doi.org/10.1016/j.rser.2016.01.117
3. Abdullah, W. S. W., Osman, M., Kadir, M. Z. A. A., & Verayiah, R. (2019). The potential and status of renewable energy development in Malaysia. Energies, 12(12), 2437. https://doi.org/10.3390/en12122437
4. Aziz, N. I. H. A., & Hanafiah, M. M. (2019b). Life cycle analysis of biogas production from anaerobic digestion of palm oil mill effluent. Renewable Energy, 145, 847–857. https://doi.org/10.1016/j.renene.2019.06.084
5. Aziz, N. I. H. A., Hanafiah, M. M., & Gheewala, S. H. (2019c). A review on life cycle assessment of biogas production: Challenges and future perspectives in Malaysia. Biomass and Bioenergy, 122, 361–374. https://doi.org/10.1016/j.biombioe.2019.01.047
6. Aziz, N. I. H. A., Hanafiah, M., Gheewala, S. H., & Ismail, H. (2020). Bioenergy for a Cleaner Future: A Case Study of Sustainable Biogas Supply Chain in the Malaysian Energy Sector. Sustainability, 12(8), 3213. https://doi.org/10.3390/su12083213
7. Aziz, N. I. H., Hanafiah, M. M., & Mohamed Ali, M. Y. (2019a). Sustainable biogas production from agrowaste and effluents: A promising step for small-scale industry income. Renewable Energy, 132, 363–369.
8. Budzianowski, W. M., & Postawa, K. (2016). Renewable energy from biogas with reduced carbon dioxide footprint: Implications of applying different plant configurations and operating pressures.
9. Chaichaloeempreecha, A., & P. C. (2019). Assessment of Thailand's energy policy on CO_2 emissions: Implication of national energy plans to achieve NDC target. RERIC.
10. Chaiprasert, P. (2011). Biogas production from agricultural wastes in Thailand. Journal of Sustainable Energy & Environment, Special Issue, 63–65. https://www.thaiscience.info/Journals/Article/JOSE/10977088.pdf
11. Conference of Biotechnology, Environment and Engineering Sciences (ICBE 2018). Alexandria, Egypt.
12. Denchak, M. (2019). Greenhouse effect 101. Natural Resources Defence Council. https://www.nrdc.org/stories/greenhouse-effect-101
13. Federal Ministry for Economic Affairs and Energy. (2015). Thailand biogas policy update (December 2015).
14. Foong, S. Z. Y., Chong, M. F., & Ng, D. K. S. (2021). Strategies to promote biogas generation and utilisation from palm oil mill effluent. Process Integration and Optimisation for Sustainability, 5, 175–191.
15. Hafizan, C., Hussein, N., & Noor, Z. Z. (2021). Life cycle assessment framework application in Malaysia. IOP Conference Series: Materials Science and Engineering, 1051(1), 012101. https://doi.org/10.1088/1757-899x/1051/1/012101
16. Hoo, P. Y., Patrizio, P., Leduc, S., Hashim, H., Kraxner, F., Tan, S. T., … & Ho, W. S. (2017). Optimal biomethane injection into natural gas grid – biogas from palm oil mill effluent (pome) in Malaysia. Energy Procedia, 105, 562-569. https://doi.org/10.1016/j.egypro.2017.03.357

17. International Organization for Standardization. (2006). ISO 14040:2006 Environmental management – Life cycle assessment – Principles and framework. ISO.
18. Jain, S. (2018). World Biogas Association market report. World Biogas Association.
19. LaMeaux, E. C. (2021). How does your carbon footprint impact climate change? GAIAM. https://www.gaiam.com/blogs/discover/how-does-your-carbon-footprint-impact-climate-change
20. Lamnatou, C., Nicolaï, R., Chemisana, D., Cristofari, C., & Cancellieri, D. (2019). Biogas production by means of an anaerobic-digestion plant in France: LCA of greenhouse-gas emissions and other environmental indicators. Science of the Total Environment, 670, 1226–1239. https://doi.org/10.1016/j.scitotenv.2019.03.211
21. Mekhilef, S., Barimani, M., Safari, A., & Salam, Z. (2014). Malaysia's renewable energy policies and programs with green aspects. Renewable and Sustainable Energy Reviews, 40, 497–504.
22. Mgbemene, C. A., Nnaji, C. E., & Nwozor, C. (2016). Industrialization and its backlash: Focus on climate change and its consequences. Journal of Environmental Science and Technology, 9(4), 301–316. https://scialert.net/fulltext/?doi=jest.2016.301.316
23. Poh, Y. H., Hashim, H., & Wai, S. H. (2018). Economic feasibility of feed-in tariff (FiT) for biomethane injection into natural gas distribution grid. Chemical Engineering Transactions, 70, 631–635.
24. Rashid, S. S., Harun, S. N., Hanafiah, M. M., Razman, K. K., Liu, Y.-Q., & Tholibon, D. A. (2023). Life cycle assessment and its application in wastewater treatment: A brief overview. Processes, 11(1), 208. https://doi.org/10.3390/pr11010208
25. Renewable and Sustainable Energy Reviews, 68, 852–868. https://doi.org/10.1016/j.rser.2016.05.076
26. Tanigawa, S. (2017). Biogas: Converting waste to energy (Fact Sheet). Environmental & Energy Study Institute. https://www.eesi.org/papers/view/fact-sheet-biogas-converting-waste-to-energy
27. Timo. (2020, January 23). From 2% to 20%: Accelerating renewable energy development in Malaysia, part 3. The Energy Bit. https://theenergybit.com/2020/01/23/from-2-to-20-accelerating-renewableenergy-development-in-malaysia-part-3/
28. Tonrangklanga, P., Therdyothina, A., & Preechawuttipong, I. (2017, May 25–26). Overview of biogas production potential from industry sector to produce compressed bio-methane gas in Thailand. In Proceedings of the 2017 International Conference on Alternative Energy in Developing Countries and Emerging Economies (AEDCEE). Bangkok, Thailand. https://www.sciencedirect.com/science/article/pii/S187661021735083X
29. U.S. Environmental Protection Agency. (2006). Life cycle assessment: Principles and practice (EPA/600/R-06/060). National Risk Management Research Laboratory.
30. Umar, M. S., Jennings, P., & Urmee, T. (2014). Generating renewable energy from oil palm biomass in Malaysia: The feed-in tariff policy framework. Biomass and Bioenergy, 62, 37–46. https://doi.org/10.1016/j.biombioe.2014.01.020
31. Umar, M. S., Urmee, T., & Jennings, P. (2018). A policy framework and industry roadmap model for sustainable oil palm biomass electricity generation in Malaysia. Renewable Energy, 128, 275–284. https://doi.org/10.1016/j.renene.2017.12.060
32. Wong, S. L., Ngadi, N., Abdullah, T. A. T., & Inuwa, I. (2015). Recent advances in the feed-in tariff in Malaysia. Renewable and Sustainable Energy Reviews, 41, 42-52. https://doi.org/10.1016/j.rser.2014.08.006
33. Yacout, D. M. M., Sirirote, P., Yacout, M. M., & Thanaboripak, D. (2018). Challenges of life cycle assessment application in Thailand biogas production. In Proceedings of the 4th International
34. Zhu, T., Curtis, J., & Clancy, M. (2019). Biogas: A real option to reduce greenhouse gas emissions. ESRI Research Bulletin, 18, 1–8.