Available online at
http://journal.uitm.edu.my/ojs/index.php/BEJ

Built Environment Journal

e-ISSN: 2637-0395

Built Environment Journal 21(Special Issue) 2024, 37 – 48.

Analysing the Factors Affecting Implementation and Cost Analysis of Biodigester Systems: Toward Sustainable Waste Management Solutions

Firas Qistina Mohd Razlan[1], Ani Saifuza Abd Shukor[2*], Saipol Bari Abd Karim[3]

[1] *RSL & Associates Sdn Bhd, No 2A&B, Jalan BK5/12a, Bandar Kinrara, 47810 Puchong, Selangor, Malaysia*
[2]*School of Construction and Quantity Surveying, College of Built Environment, Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Malaysia*
[3]*Faculty of Built Environment, Universiti Malaya, 50603, Universiti Malaya, Wilayah Persekutuan, Malaysia*

ARTICLE INFO

Article history:
Received 24 July 2024
Revised 20 August 2024
Accepted 30 August 2024
Online first
Published 30 September 2024

Keywords:
Waste Management
Food Waste
Biodigester System
Anaerobic Digestion
Cost Analysis

DOI:
10.24191/bej.v21iSpecial Issue.2436

ABSTRACT

Biodigester systems have recently drawn attention as an innovative and long-term solution to food waste since they use organic waste to produce biogas and bio-fertilisers rather than dump food waste in landfills. Food waste is a worldwide problem that negatively impacts on the environment, society, and economy. Therefore, implementing a biodigester system will reduce food waste issues. The conversion of food waste to biogas has high potential as a sustainable waste management solution. This study aims to establish a deeper understanding of implementing a biodigester system by identifying the factors to consider when implementing a biodigester system and analysing the associated costs. This study utilises three case studies of three (3) biodigester systems in Klang Valley that three (3) local authorities have implemented, as well as semi-structured interviews with assistant directors from the local authorities. As for the outcome, the feedstock supply is the factor to consider when implementing a biodigester system, and its cost ranges from RM 200,000.00 to RM 450,000.00. The output of the study can be deployed as a lead to boost its implementation and improvement in the future.

[2*] Corresponding author. *E-mail address*: anisa278@uitm.edu.my

INTRODUCTION

Malaysia is a lively and diverse country known for its rich culinary traditions however, the growing issue of food waste cannot be ignored. Therefore, food waste impact can be harmful to society, the environment, and the economy (Abdul et al., 2021). According to Food and Agriculture (2019), food waste impacts the environment through greenhouse gas emissions, climate change, the footprint of water consumption, and the impact on biodiversity. Globally, there is an increasing focus on food waste, and Malaysia is no different. To support this, the International Trade Administration (ITA) 2022, stated that food waste contributed the most significant component of Municipal Solid Waste (MSW), followed by plastic, paper, mixed organic, and others. Furthermore, in the circular economy and concerning Sustainable Development Goals (SDG) 12, the waste sent to landfills shall be reduced by improving the recycling rate. This can prevent emissions related to solid waste from increasing by 2.6 billion tons of carbon dioxide by 2050.

Solid Waste Management (SWM) regulates the production, storage, collection, transfer, and disposal of Solid Wastes (SW) (Syifaa et al., 2023). Waste residues can be transformed into alternative energies such as biogas, electricity, and heat. Using a biodigester system, particularly anaerobic digestion, presents a promising and sustainable solution for treating food waste (Nuhu et al., 2021). Despite the slow adoption of this new technology in Malaysia, the potential benefits of a biodigester are compelling and warrant a detailed exploration.

Food waste is a global problem with significant negative impacts on the environment, society, and economy (Seberini, 2020). The environmental impacts of food production, particularly throughout the food chain, have been linked to global warming. When food waste is not recycled, it is often dumped in landfills where it decays and releases methane. Rashidi et al (2022) stated that this potent greenhouse gas is 25 times more powerful than carbon dioxide and has been used for animal feed and agriculture is increasingly recognised as a financially viable option to reduce food waste, especially in the context of rising energy costs and growing public concerns about environmental degradation.

Furthermore, landfilling, the least desirable method of waste disposal, requires expensive and time-consuming physical, chemical, and biological treatment and segregation of wastes (Abuabdou et al., 2020). In Malaysia, reliance on landfills alone is not sustainable, and thus, there is investment in an incinerator machine called a biodigester as a disposal solution. However, the implementation of biodigesters in Malaysia faces challenges related to funding, government coordination, and achieving synergy between planning and programs despite the potential benefits (Ali et al., 2022). Moreover, the upfront installation costs hinder the widespread use of biodigester systems in Malaysia, which can be particularly expensive for small-scale farms, rural communities, and local governments.

Therefore, using a biodigester system, anaerobic digestion is the most sustainable way to treat food waste. However, Malaysians are still taking time their adopt the new biodigester technology. Thus, more studies are needed on the cost of biodigester systems in Malaysia (Lim et al., 2021). Given the undetermined costs, a comprehensive examination of Malaysia's biodigester system's cost is also necessary. This is precisely why a biodigester is appealing and needs to be explored in detail. Thus, this paper focuses on the factors to consider in implementing a biodigester system and analyses the cost associated with constructing a biodigester system.

https://doi.org/10.24191/ bej.v21iSpecialIssue.2436

LITERATURE REVIEW

An Overview of Food Waste

Environmental impacts are changes to the created or natural environment that are the direct outcome of an activity and may have negative effects on fish, animals, the air, land, or ecosystem inhabitants (Panagiotopoulou et al., 2022). Spiru et al. (2023) mentioned that waste occupies a large amount of landfill area and harms the environment, including leachate formation, unpleasant odours, and greenhouse gas emissions from the MSW's breakdown. Therefore, instead of letting the wastes decompose and release harmful gases, it is advisable to use by products to produce heat and energy. Lai et al. (2017) suggested that if anaerobic digesters are utilised, the digestated may be used as fertiliser rather than disposed of, however utilising an incinerator to manage the waste would cut the volume by 95%.

Due to the overflowing landfills, Malaysia faces the risk of running out of room for the disposal of solid waste by 2050. (Kamaruddin et al., 2017) supported that with over 100 landfills receiving an average of 38,000 metric tonnes of solid garbage every day in Malaysia, operators and authorities are working hard to find solutions for the country's trash disposal needs.

Even though there is enough food produced in the entire world, malnutrition and hunger affect around a billion people (Seberini, A. 2020). Tonnes of food that could be devoured in developing countries are wasted in many wealthy countries. While some people have access to enough food, even in excess, socially disadvantaged populations often lack the means to purchase nutritious food or, in other cases, do not have any food at all. Therefore, to effectively reduce food waste, it is crucial to implement comprehensive and efficient solid waste management practices.

Challenges in Solid Waste Management

Since it is the most affordable and widely used technique of treating solid waste with a high percentage of organic components, open dumping landfills are preferred (Das et al., 2019). Numerous serious environmental effects result from open dumping, including leachate-induced contamination of soil, groundwater, and surfaces; air pollution from burning wastes; disease transmission by various vectors, including birds, insects, and rodents; landfill odour; and uncontrollably high levels of methane released during the anaerobic waste breakdown. Latifah Abd Manaf., (2022) mentioned that river water was exposed to a significant danger of leachate contamination when landfill disposal was used unless appropriate leachate management was implemented. There is currently very little information available regarding the effects of leachate from both managed and uncontrolled landfills on Malaysian rivers.

In Malaysia, 38,000 metric tonnes of municipal solid waste are dumped at dumpsites every day by garbage trucks. Eight (8) sanitary landfills, three (3) inert landfills for materials like concrete and sand, and 165 other landfills exist, all of which are nearing capacity. Only 5% of garbage is delivered to small-scale thermal treatment plants in various areas, including Cameron Highland, Pangkor, Langkawi, and Tioman, according to. As waste collection expands across Malaysia, reliance on landfills will only grow in the absence of appropriate solid waste management techniques or technology.

Utilising waste combustion on a small scale is the only way that incineration is used as a biodigester system in Malaysia. Incineration can reduce MSW volume by 80% - 95% in total. The Ministry of Local Government and Housing (MHLG) Malaysia started several incinerator projects in 2011 to manage MSW, spending RM 187.74 million in total. These featured five (5) rotary kiln-style small-scale incinerators that were installed in five (5) popular tourist destinations: Cameron Highland (40 tons/day), Pulau Pangkor (20 tons/day), Pulau Tioman (10 tons/day), and Pulau Langkawi (100 tons/day). Yong et al., (2019) concluded

https://doi.org/10.24191/ bej.v21iSpecialIssue.2436

that when comparing the initial and operating costs of building an incinerator to a sanitary landfill, the estimates are roughly ten (10) and three (3) times higher, respectively.

Sustainable Waste Management and Biodigester System

The main goal of sustainable waste management is to minimise the adverse effects of waste handling and disposal, underscoring the urgent need for waste reduction in the context of sustainability (Keter Environmental Services., 2024). In Malaysia, the challenge of managing the burgeoning volume of food waste in an environmentally sustainable manner is critical, given the country's rapid urbanisation and the resulting increase in waste, which highlights an urgent need for sustainable alternatives (A. Shukla et al., 2024).

Anaerobic digestion is a procedure that uses a device called a biodigester system to turn organic waste into biogas and organic fertiliser (Forero et al., 2019). This system is made to decompose organic waste in a sealed, oxygen-free environment, including food scraps, agricultural waste, and sewage sludge. In this procedure, (Lim et al., 2021) stated that bacteria are utilised to break down organic material and create biogas, a renewable energy source that may be used for cooking, heating, and producing power. A biodigester's main purpose is to turn sludge, household waste, blackwater, and animal manure into biogas that may be utilised in homes for cooking, heating, and lighting (Wang et al., 2019). These items ought to be used outside, where day-to-day and moment-to-moment variations in operation conditions are substantial. By using a biodigester, manure can be converted into methane or cooking gas. Once the biodigester is established, this procedure is reasonably affordable to operate and requires little to no technical expertise.

Plus, a biodigester system's ability to manage garbage in an eco-friendly and sustainable manner is one of its main advantages. Therefore, this technology can help decrease the amount of garbage that ends up in landfills, which can help lower greenhouse gas emissions and increase soil fertility. It does this by transforming organic waste into biogas and fertiliser (Aziz et al., 2020). A biodigester system can also generate biogas, a renewable energy source that can help lessen reliance on fossil fuels and promote a more sustainable energy future (Yong et al., 2021).

To conclude, biodigester systems are a sort of technology that can use anaerobic digestion to transform organic waste into biogas and organic fertiliser (Muvhiiwa et al., 2017). This method can lower greenhouse gas emissions and is both economical and environmentally friendly. Systems with biodigesters can be utilised in several contexts and offer a sustainable waste management solution that is advantageous to the economy and the environment (Ebeya et al., 2022).

Advantages of Biodigester System

Implementing biodigester systems also involves the advancement of technology in Malaysia to convert biomass resources into elements that may be used. The sustainable growth of the energy sector depends on the government's collaboration with academic institutions to investigate the potential of biomass-producing gases utilising various technical approaches (Muvhiiwa et al., 2017). It is imperative to consider the biodigester's system overall sustainability, considering upstream activities and electricity sources. The Malaysian government's dedication to maintaining the sustainability of energy supplies in the face of rising energy needs is demonstrated by the ongoing evaluation of its energy strategy (Kalaiselvan et al., 2022). This pledge is in line with the worldwide movement towards renewable energy sources and resource preservation for a more sustainable future.

Next, the possibility of achieving energy independence is another benefit of putting in place a biodigester system in Malaysia. Communities become less dependent on conventional energy sources

https://doi.org/10.24191/ bej.v21iSpecialIssue.2436

thanks to biodigesters, which offer a decentralised energy alternative. To lessen the effects of changes in energy prices and supply interruptions, this independence is crucial (Cruz-Monterrosa & Ramirez Bribiesca, 2022). Besides achieving energy independence, the use of biodigester systems can help Malaysia with its water shortage problem. It is possible to lessen reliance on the national grid for electricity by generating electricity using biogas. Moreover, the integration of rainwater collecting into the biodigester system might provide a substitute water source, so aiding in the alleviation of water scarcity issues in areas confronting such difficulties.

Due to Malaysia's heavy reliance on landfills for waste disposal, the nation may eventually face serious space restrictions, health problems, and environmental challenges. As a result, installing a biodigester can drastically save waste management expenses because trash can be handled locally rather than being transported to landfills or incinerators. More specifically, biodigesters are low maintenance and only need to be purchased once (Meyer et al., 2021). Additionally, installing a high-quality biodigester helps save repair costs. Biodigesters also free up employees' time for labour and time-intensive chores, allowing them to concentrate on other activities that may bring in money.

Factors Affecting the Implementation of Biodigester System

Several known variables affect the plant size selection, adoption, and biodigester output. Among these include the availability of feedstock, money, environmental consciousness, and local political governance (Yang, Liu, Thran, Bezama & Wang, 2021). There are many different sizes and levels of sophistication for biogas facilities. Biogas plants include balloon plants, fixed-dome plants, floating-drum plants, and portable biogas plants. The scale of the biogas plant under consideration is, however, limited by technical issues such as the size of the digester and/or gasholder. Hydraulic Retention Time (HRT) refers to the average amount of time that the slurry or substrate is held inside the digester. It establishes the biodigester's dimensions and, thus, the plant's price. Long-term retention of the slurry is indicated by a high HRT. In these circumstances, the construction of a sizeable biogas plant is necessary. Conversely, a low retention time indicates that the slurry passes through the biodigester quickly. As a result, in. the production of biogas, hydraulic duration is directly correlated with plant size.

Besides, the amount of feed material that needs to be given to the biodigester each day is important as a large-scale biogas plant building is aided by abundant feedback. Hence, standard-sized biogas plant construction is encouraged by the low volumes of feedstock provided to the biogas plant. Biodigester can be stored in the area provided by the gasholder. It depends directly on the cylinder. The selected gasholder size should have enough capacity to keep gas produced daily and be able to accept gas produced both within and outside of consumption periods. In comparison to a combination of a modest biodigester and gasholder size, a large biogas digester and gasholder would ultimately result in a huge biodigester plant. Nevertheless, the size of the biodigester plant is largely dependent on how it will be used. A household, business, school, or even the entire town could benefit from the biogas plant. The size of each of these institutions varies.

According to Mohamed Zaki et al., (2020), there are several types of portable biodigester systems for household use. Some common ones are as:

(i) Fixed dome: it has an inlet chamber feeding into the digester, which is topped by a dome expansion chamber with a gas release point to discharge biogas produced, and is constructed of granite, sharp sand iron rods, and cement.

(ii) Floating drum: the biodigester has a central guide installed inside of it to reduce the possibility of an explosion and avoid tilting. Like the fixed-dome design in operation, the primary system is more effective and offers greater room for biogas storage.

https://doi.org/10.24191/ bej.v21iSpecialIssue.2436

(iii) Plug flow biodigester: the design was designed to longitudinally separate the two (2) processes of acetogenesis and methanogenesis. With a solid content ranging from 11% to 14% and an HRT between 20 and 30 days depending on the size of the biodigester.

(iv) Low-cost polyethylene tube biodigester: the amount of biogas produced is based on the temperature outside and provides an anaerobic digestion tank that is airtight. It is easier to build than a fixed-dome or floating drum, and it uses a feeding port, effluent port, and biogas output to function. The effluent port's level serves as the basis for a hydraulic level.

(v) Small-scale anaerobic digester: an anaerobic digester technology known as a small-scale biogas reactor or anaerobic digester generates two (2) products: (a) digested slurry, or digest-estate, which can be used as fertilizer, and (b) biogas, which can be utilized as a source of energy. Methane, carbon dioxide, and other trace gases combine to form biogas, which can be used to generate heat, electricity, or light. In rural settings, small-scale biogas reactors are usually intended to generate biogas at the household or community level.

(vi) Balloon biodigester: A heat-sealed plastic or rubber bag that combines digestion and biogas storage is known as a balloon bio-digester. By increasing the external load, the inner pressure can be raised, but safety valves must be added. The employed material is UV and extremely weather-resistant, and it is significantly less expensive than a fixed dome or floating drum bio-digesters. Limitations include a reduced life expectancy and the possibility of leakage having an impact on anaerobic digestion.

A review of water resource availability and accessibility is necessary for the criteria to build a biodigester system. It might be necessary to look at alternate options or changes to the biodigester system if there are areas of Malaysia with limited water supplies to maintain the system's sustainability without using too much water. When establishing biodigester systems, crop kinds, and soil factors should also be considered. The characteristics of the soil and the farming methods used in various parts of the nation have a direct impact on how effective the technology is. To optimise the performance of biodigester systems and their impact on agricultural output, site-specific studies assessing the systems' compatibility with local crop kinds and soil conditions are crucial.

To guarantee the materials' effectiveness, longevity, and affordability, biodigester systems in Malaysia need to be built with great care. Quiroga et al. (2019) suggested that building biodigester systems requires a few critical construction materials. The extended storage causes the cement to gradually lose its binding strength. For best results, it is always preferable to use new cement. For the construction of plants, standard Portland 42.5 grade cement that is readily available locally is chosen. It is advisable to avoid placing cement near any walls. There should be no lumps in the cement. Should there be any tiny lumps, it is brittle. Sand used in construction projects must be pure, and devoid of dirt and organic materials. Unclean sand will have a significant effect on the building. For plastering, fine sand should be used, and for concreting, coarse and granular sand should be used. Avoiding dusty sand is advised at all costs. There are many pebbles in this sand, ranging in size from 10 mm to 500 mm. Sieving is required before using this. When building a biogas plant, sand needs to be free of clay and dirt. Pebbles from riverbeds are the most used. Since the pebble surface is smooth, the cement in the concrete mix cannot be held in place. Concreting requires larger surface areas. For concrete, strong, hard stone aggregates with a rough surface are required. 37 m3 of this material must be purchased at a time in larger quantities. Despite being nearly three (3) times more expensive than pebbles, this substance is nonetheless expensive. The ideal size for the granite stone chunks is between 20 and 25 mm.

Cost Analysis of Biodigester System

https://doi.org/10.24191/ bej.v21iSpecialIssue.2436

Patinvoh & Taherzadeh, 2019 stated that the high capital cost, lack of knowledge or confidence among financiers and/or investors, lack of the proper financing scheme, competition from fossil fuels, and lower subsidies when compared to conventional fuel are some of the factors that make up the economic barrier. With priority factors of 0.442 and 0.349, respectively, the Malaysian government and industry view the high capital investment required as the biggest obstacle to the use of biomass for energy production. Viancelli et al., (2019) revealed that the initial investment required to establish a biogas plant in Malaysia can amount to RM 10 million, posing difficulties for the developers because of the lengthy payback period. Here, switching from conventional boilers to grid-connected high-pressure boilers and relying on imported machinery might result in such a large expenditure.

A crucial component of project planning for biogas is cost. Overcharging could scare off prospective customers while undercharging could force the developer to file for bankruptcy or sacrifice quality.

(i) Materials

The plant's cost should be determined by considering the current market price of all building supplies. For example, the cost of cement, bricks, and sand varies significantly depending on where you live. The project's location should always be considered (Jesus et al., 2021). In addition, the raw material availability—particularly that of burnt or concrete bricks—must be considered. The long-distance transportation of these materials will affect the project's ultimate cost. All supplies must be obtained from sources closest to the plant's location, if feasible. The cost of transporting items from the vendor to the site should be considered.

(ii) Labor

One of the main expenses associated with building a biodigester in Malaysia is labor. The number of skilled and unskilled workers needed for the project's execution will depend on its scale (Mendieta et al., (2021). A good strategy would be to hire the necessary number of workers while maintaining quality standards. Each competent mason hired can collaborate with no more than two (2) unskilled laborers. Apart from professional laborers like masons, electricians, plumbers, and bricklayers, all other workers may be found locally to save costs.

(iii) Other costs

Some crucial components that entail costs and should not be disregarded are:

(i) Excavation
(ii) Site Clearing
(iii) Site Preparation
(iv) Design Cost
(v) Backfilling Cost

RESEARCH METHODOLOGY

Research design refers to the organisation and implementation of specific research. It requires methodologies that complement research methods to produce credible results. To examine social and cultural phenomena, researchers in the social sciences have developed the qualitative research approach, which involves observing people's feelings, thoughts, behaviours, and beliefs in general. This study used qualitative research and a case study approach in this investigation. The case study approach was chosen for its ability to provide in-depth understanding and insights into the implementation of a biodigester system

https://doi.org/10.24191/ bej.v21iSpecialIssue.2436

within Klang Valley, which three (3) Local Authorities have implemented. The data is gained from semi-structured interviews, with the primary focus being the assistant directors involved with implementing a biodigester system. This will strengthen the accuracy of the information gathered because of their extensive experience and understanding of the biodigester system.

The analysis, based on cross-case analysis and pattern matching, was conducted with meticulous attention to detail. The researchers diligently sought similar relationships across all case studies and matched the pattern of similarities to confirm and generalise the findings. Structured and standardised processes, collection, and analysis methods were employed for cross-case comparisons. Table 1 shows the respondents' profile overviews based on the interviews of each case study. The overviews comprise their working experiences, positions, and representative Local Authority.

Table 1: Respondents' Overview and Biodigester System Characteristics

Respondent	Respondent 1	Respondent 2	Respondent 3
Working Experience	11 Years	12 Years	12 Years
Position	Assistant Director	Assistant Director	Assistant Director
Local Authority	Case Study 1	Case Study 2	Case Study 3
Placement of the biodigester system	Food Court	Market	Food Court

Source: Authors (2024)

Findings from semi-structured interviews based on three (3) comparative case studies revealed that the same factors are applied to the case studies, but due to some reasons for considering it, the type and components are varied for each case study. This rigorous approach ensures the validity of the findings and a comprehensive understanding of how a biodigester system is implemented.

FINDINGS AND DISCUSSIONS

Factors Affecting the Implementation of Biodigester System

After analysing the data individually and cross-case is carried out, Table 2 shows that the biodigester system's capacity, feedstock supply, and Hydraulic Retention Time (HRT) are critical factors in implementing a biodigester system.

Table 2. Analysis Found from the Interviews

Description		**Case Study 1**	**Case Study 2**	**Case Study 3**
Factors to consider	Feedstock supply	/	/	
	Capacity of the biodigester	/	/	/
	HRT			/
Type of biodigester system		Small scale anaerobic digester	Small scale anaerobic digester	Small scale anaerobic digester
Components	Grinder	/	/	
	Filter	/	/	

https://doi.org/10.24191/ bej.v21iSpecialIssue.2436

Pipe	/		
Digester Tank	/		/
Bearing System	/		
Inner Chamber		/	
Compressor		/	
Water Pump		/	
Storage Bag			/
Power Generator			/

Source: Authors (2024)

From the table above, all three (3) case studies use the same type of biodigester system, which is a small-scale anaerobic digester. Even though all three (3) case studies use the same type of biodigester system, their components can differ. A similar factor to consider when implementing the biodigester system is the capacity of the biodigester system, which can accommodate 500 kg of food waste per day. The main factor considered when implementing the biodigester system in all case studies in this research is the capacity of the biodigester system. This is because Schoeber et al., (2020) supported that the maximum capacity of the biodigester system is to fit 500kg of waste per day. Next, the feedstock supply is essential because the system needs every supply hour to ensure that the microorganisms are alive from the feedstock and the system will keep operating. However, Case Study 3 did not consider feedstock supply as the main factor; the primary consideration is the Hydraulic Retention Time (HRT). HRT is the typical amount of time that the raw material is stored inside the digester, which is 26 days. With the justification of Viancelli et al., (2019), 26 days is long enough for the raw materials to be kept inside the digester system. All three (3) case studies utilise the same type of biodigester system, which is the small-scale anaerobic digester, as it is easier to function, there is no foul odour produced, and it can compost all kinds of organic matter and food waste supported by (Mahmudul et al., 2021). Apart from utilising the same type of biodigester system, some components are different. In Case Study 1, there are conveyors and bearing systems. In Case Study 2, inner chambers, air compressors, and replacement device hammers are used. Lastly, in Case Study 3, there are anaerobic digestion reactors, wet and dry desulfurisers, and gas storage bags. Other than the components, they used the same components within each other.

Cost Analysis of Biodigester System

The construction cost of this system was collected through semi-structured interviews with the assistant director involved. The cost embraced in the biodigester system is based on labour, utilities, basic materials, machine and maintenance, and other costs supported by Mendieta et al., (2021). Hence, the detailed cost of each component involved in this system can be analysed up to that point only. Based on the conducted cross-case study analysis, the findings reveal significant differences in construction costs. Case Study 2 has the highest construction cost with RM 450,000.00 as the local authority was dealing with a private company, Mentari Alam (M) Eko Sdn Bhd, which specialises in food waste composters. This case highlights the potential for cost savings through collaboration with private companies. Case Study 3, with a cost of RM 300,000.00, demonstrates the benefits of collaboration with organisations like Perbadanan Pengurusan Sisa Pepejal dan Pembersihan Awam (SWCORP). Lastly, Case Study 1 has the lowest construction cost, with RM 269,920.00, as the machine was built in 2014. This case underscores the

https://doi.org/10.24191/ bej.v21iSpecialIssue.2436

importance of considering the age of the machine in determining construction costs. The local authority was appointed by SIRIM Berhad to provide a space and raise awareness among local citizens, further demonstrating the multifaceted nature of cost considerations.

Table 3. Cost Analysis Found from Interviews

Cost Analysis of Biodigester System		Case Study 1	Case Study 2	Case Study 3
Method of costing (RM)	Labour Cost	254,000.00	435,000.00	283,000.00
	Utilities	6,320.00	5,000.00	6,700.00
	Basic Materials	500.00	1,500.00	1,000.00
	Machine and Maintenance	3,000.00	5,300.00	7,000.00
	Other Cost	1,200.00	3,200.00	2,300.00
TOTAL (RM)		269,920.00	450,000.00	300,000.00

Source: Authors (2024)

CONCLUSION

Current research demonstrates that the biodigester system implementation in all three (3) case studies was primarily based on its capacity, feedstock supply, and Hydraulic Retention Time (HRT). The biodigester system, a small-scale anaerobic digester, was chosen for its ease of use, no foul odour, and composability of organic matter and food waste. Different components were used in each case study, such as conveyors, bearing systems, inner chambers, air compressors, and gas storage bags. However, all components used in all three (3) case studies were consistent. The overall costs of the biodigester system for the three (3) case studies are obtained and compared. The cost was based on labour, utilities, basic materials, machines, and maintenance. Case Study 2 had the highest cost at RM 450,000, while Case Study 3 had the second highest at RM 300,000. Case Study 1 had the lowest cost at RM 269,920.00.

Based on the conducted research, a few suggestions can be made for future research. Since this study focused on the factors to be considered when implementing the biodigester system, it is recommended that a study on site selection be carried out when installing the system. This is because when placing a biodigester system in a non-strategic place, the system will not receive an encouraging response from the citizens. It is also recommended that the life-cycle cost of the biodigester system be studied. By examining the cost, the local government can predict the return on investment in implementing this system, potentially leading to significant cost savings in the long run.

ACKNOWLEDGEMENTS

The author would like to dedicate their heartiest thanks to the present study participants, and Universiti Teknologi MARA for providing support and assistance

CONFLICT OF INTEREST STATEMENT

The authors confirm that this research was carried out without any personal, commercial, or financial conflicts and state that they have no conflicting interests with the funders.

https://doi.org/10.24191/ bej.v21iSpecialIssue.2436

REFERENCES

A. Shukla, K., Bin Abu Sofian, A. D. A., Singh, A., Chen, W. H., Show, P. L., & Chan, Y. J. (2024). Food waste management and sustainable waste to energy: Current efforts, anaerobic digestion, incinerator and hydrothermal carbonization with a focus in Malaysia. *Journal of Cleaner Production*, *448*, 141457. https://doi.org/https://doi.org/10.1016/j.jclepro.2024.141457

Ali, S., Yan, Q., Razzaq, A., Khan, I., Irfan, M., & Irfan, M. (2022). Modeling factors of biogas technology adoption: a roadmap towards environmental sustainability and green revolution. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-022-22894-0

Abuabdou, S. M. A., Ahmad, W., Aun, N. C., & Bashir, M. J. K. (2020). A review of anaerobic membrane bioreactors (AnMBR) for the treatment of highly contaminated landfill leachate and biogas production: Effectiveness, limitations and future perspectives. *Journal of Cleaner Production*, *255*, 120215. https://doi.org/https://doi.org/10.1016/j.jclepro.2020.120215

Das, S., Lee, S.-H., Kumar, P., Kim, K.-H., Lee, S. S., & Bhattacharya, S. S. (2019). Solid waste management: Scope and the challenge of sustainability. *Journal of Cleaner Production*, *228*, 658–678. https://doi.org/https://doi.org/10.1016/j.jclepro.2019.04.323

Jesus, R. H. G. de, Souza, J. T. de, Puglieri, F. N., Piekarski, C. M., & Francisco, A. C. de. (2021). Biodigester location problems, its economic–environmental–social aspects and techniques: Areas yet to be explored. *Energy Reports*, *7*, 3998–4008. https://doi.org/https://doi.org/10.1016/j.egyr.2021.06.090

Kamaruddin, M. A., Yusoff, M. S., Rui, L. M., Isa, A. M., Zawawi, M. H., & Alrozi, R. (2017). An overview of municipal solid waste management and landfill leachate treatment: Malaysia and Asian perspectives. *Environmental Science and Pollution Research*, *24*(35), 26988–27020. https://doi.org/10.1007/s11356-017-0303-9

Lim, Y. F., Chan, Y. J., Abakr, Y. A., Sethu, V., Selvarajoo, A., Singh, A., Lee, J., & Gareth, M. (2021). Review of biowastes to energy in Malaysia: Current technology, scalability, and socioeconomic analysis. *Cleaner Engineering and Technology*, *4*, 100257. https://doi.org/https://doi.org/10.1016/j.clet.2021.100257

Mahmudul, H. M., Rasul, M. G., Akbar, D., Narayanan, R., & Mofijur, M. (2021). A comprehensive review of the recent development and challenges of a solar-assisted biodigester system. *Science of The Total Environment*, *753*, 141920. https://doi.org/https://doi.org/10.1016/j.scitotenv.2020.141920

Mendieta, O., Molano, L. del P. C., Castro, L., Vera, E., Rodríguez, J., & Escalante, H. (2021). Toward the Adoption of Anaerobic Digestion Technology through Low-Cost Biodigesters: A Case Study of Non-Centrifugal Cane Sugar Producers in Colombia. *Water*. https://doi.org/10.3390/w13182566

Mohamed Zaki, M. B. A., Shamsudin, R., & Mohd Yusoff, M. Z. (2020). Portable Biodigester System for Household Use – A review. *Advances in Agricultural and Food Research Journal*, *2*(October 2020). https://doi.org/10.36877/aafrj.a0000148

Mohamed Zain, I. N., & Abdul Rahman, H. (2021). Food Waste Management and Green Purchasing Behaviour Among Youths in Malaysia. *International Journal of Academic Research in Business and Social Sciences*, *11*(15). https://doi.org/10.6007/IJARBSS/v11-i15/10635

https://doi.org/10.24191/ bej.v21iSpecialIssue.2436

Nuhu, S. K., Gyang, J. A., & Kwarbak, J. J. (2021). Production and optimization of biomethane from chicken, food, and sewage wastes: The domestic pilot biodigester performance. *Cleaner Engineering and Technology*, *5*, 100298. https://doi.org/https://doi.org/10.1016/j.clet.2021.100298

Panagiotopoulou, V. C., Stavropoulos, P., & Chryssolouris, G. (2022). A critical review on the environmental impact of manufacturing: a holistic perspective. *The International Journal of Advanced Manufacturing Technology*, *118*(1), 603–625. https://doi.org/10.1007/s00170-021-07980-w

Rashidi, N. A., Yusup, S., & Chai, Y. H. (2022). Biomass Energy in Malaysia: Current Scenario, Policies, and Implementation Challenges. *BioEnergy Research*, *15*. https://doi.org/10.1007/s12155-022-10392-7

Schoeber, M., Rahmann, G., & Freyer, B. (2020). Small-scale biogas facilities to enhance nutrient flows in rural Africa—relevance, acceptance, and implementation challenges in Ethiopia. *Organic Agriculture*. https://doi.org/10.1007/s13165-020-00329-9

Seberini, A. (2020). Economic, social, and environmental world impacts of food waste on society and Zero waste as a global approach to their elimination. *SHS Web Conf.*, *74*. https://doi.org/10.1051/shsconf/20207403010

Spiru, P. (2023). Assessment of renewable energy generated by a hybrid system based on wind, hydro, solar, and biomass sources for decarbonizing the energy sector and achieving a sustainable energy transition. *Energy Reports*, *9*, 167–174. https://doi.org/10.1016/j.egyr.2023.04.316

Syifaa, N., Shakil, M., Zahida, A., Azhar, M., & Othman, N. (2023). Solid Waste Management in Malaysia: An overview. In *Information Management and Business Review* (Vol. 15, Issue 1).

Panagiotopoulou, V. C., Stavropoulos, P., & Chryssolouris, G. (2022). A critical review on the environmental impact of manufacturing: a holistic perspective. *The International Journal of Advanced Manufacturing Technology*, *118*(1), 603–625. https://doi.org/10.1007/s00170-021-07980-w

Patinvoh, R. J., & Taherzadeh, M. J. (2019). Challenges of biogas implementation in developing countries. *Current Opinion in Environmental Science and Health*, *12*, 30–37. https://doi.org/10.1016/j.coesh.2019.09.006

What Is Sustainable Waste Management? (2024). https://www.keteres.com/technology/sustainable-waste-management

https://doi.org/10.24191/ bej.v21iSpecialIssue.2436