Assessing the Environmental and Economic Benefit of Implementing Waste to Energy Technology

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Abstract- The study assesses the environmental and economic benefits of implementing waste-to-energy technology. It utilized a laboratory research method as its study design. Different types of waste were collected and sorted out accordingly. The wastes where then pre-treated for an easy conversion process and eco-friendly. Several methods of waste method, ranging from Anaerobic Digestion, Pyrolysis, Gasification and Incineration. These methods of waste management were all compared and from the result of the analysis, it was noted that the most effective, cost-effective and sentimental friendly is the Anaerobic Digestion and Pyrolysis method. This method converts waste cooking gas, and into electricity without causing damage to the environment. Based on this finding, the study recommended that both government and the society should utilize Pyrolysis and anaerobic digestion method of waste management which is the most effective and cost-effective method of waste management system in managing their menace of waste.

Indexed Terms- Environment, Economic Benefit, Waste Management, Energy & Technology

I. INTRODUCTION

Waste management poses a significant challenge worldwide, with increasing amounts of waste generated each year. However, advancements in waste-to-energy (WtE) technologies offer promising solutions to address this issue. waste-to-energy (WtE) technologies encompass various processes that convert waste into usable forms of energy, such as electricity, heat, or fuel. Traditional way of waste disposal methods, including landfilling, contribute to environmental pollution and greenhouse gas emissions. By diverting waste from landfills, waste-to-energy technologies help reduce the amount of waste accumulating in these sites. According to a study by Tang *et al.* (2018), waste-to-energy (WtE) technologies can significantly decrease the volume of waste deposited in landfills, thereby mitigating associated environmental risks.

One of the major advantages of waste-to-energy systems is their potential to mitigate greenhouse gas emissions. Instead of allowing waste to decompose in landfills and release methane—a potent greenhouse gas— waste-to-energy (WtE) technologies can capture methane and convert it into energy. According to the Environmental Protection Agency (EPA, 2020), waste-to-energy (WtE) processes significantly reduce methane emissions, thereby helping combat climate change.

Implementing waste-to-energy technologies facilitates the recovery of valuable resources from waste streams. Through processes like anaerobic digestion and incineration, organic waste can be transformed into biogas or biofuels, reducing the reliance on fossil fuels. Moreover, waste incineration can generate electricity and heat, offering opportunities for energy diversification. This resource recovery contributes to the promotion of a circular economy, reducing the need for extraction of virgin materials (Euractiv, 2019).

Waste-to-energy technologies provide a reliable source of renewable energy, reducing dependence on conventional fossil fuels. The electricity and heat generated from waste can be used to power industrial facilities, homes, and other infrastructure. This diversification of energy sources contributes to energy security and can potentially stabilize electricity prices (Zhang *et al*., 2019). In addition, according to a report by Frost & Sullivan (2020), waste-to-energy (WtE) technologies have the potential to deliver cost savings in waste management, as they offset expenses related to landfilling and waste transportation. The implementation of waste-to-energy technologies can stimulate job creation and foster economic growth. waste-to-energy (WtE) projects require a skilled workforce for construction, operation, and maintenance, providing employment opportunities in local communities (Chen *et al.,* 2018). Furthermore, the development of the waste-to-energy sector can attract investments, create new businesses, and stimulate technological innovation, leading to overall economic development (Ellen MacArthur Foundation, 2020). This is why this study focus on assessing the environmental and economic benefit of implementing waste to energy technology.

- Statement Of the Problem

The proper management of waste is a critical global concern due to its detrimental environmental impacts and associated economic costs. Traditional waste management practices, such as landfilling and open dumping, not only contribute to pollution but also lead to the loss of valuable resources. However, implementing waste-to-energy (WtE) technologies offers a potential solution to address these challenges. The first aspect of the problem relates to the significant environmental challenges posed by conventional waste management practices such as landfills which is the most common method of waste disposal, leads to several adverse environmental effects. It results in the release of greenhouse gases, particularly methane, a potent contributor to climate change. Furthermore, landfills can contaminate soil, water bodies, and surrounding ecosystems through leachate, a toxic liquid produced from decomposing waste. The continuous accumulation of waste in landfills exacerbates these problems and poses a threat to public health and biodiversity. The second aspect of the problem pertains to the economic costs associated with inefficient waste management. Conventional waste disposal methods require vast land areas for landfills, leading to escalating costs of land acquisition and maintenance. Moreover, waste transportation to distant disposal sites incurs substantial expenses, including fuel consumption and labor costs. Inefficient waste management systems result in a loss of potential economic value, as valuable resources within the waste stream, such as organic matter and recyclables, are not effectively recovered or utilized. These problems necessities this study into assessing the environmental and economic benefit of implementing waste to energy technology.

- Objective Of the Study

The major objective of the study is to assess environmental and economic benefit of implementing waste to energy technology. The specific objective is to;

- Identify the various type of waste
- Convert waste to energy for as a means of cost-effective waste management system.

The study will be of benefit to government and to the society. Government will benefit from the study as the study will help them know how to effectively manage waste and also be able to re-use it for economic benefit. Society will see the need of adopting and using the effective way of waste disposing system since the study will make them see and appreciate the best method of waste management.

II. LITERATURE REVIEW

Waste management is a pressing global concern due to its significant impact on the environment. Improper disposal and mismanagement of waste can lead to severe environmental consequences, including pollution of air, water, and soil, as well as the depletion of natural resources. There are different type of waste and these are as follows.

- Municipal Solid Waste (MSW)

Municipal solid waste, commonly known as household waste, comprises various items discarded by households, businesses, institutions, and industries. The generation of Municipal solid waste has been rapidly increasing due to population growth, urbanization, and consumerism (Abdullah *et al.,* 2021). Municipal solid waste includes organic waste, paper, plastics, glass, metals, and hazardous substances. When not adequately managed, Municipal solid waste can lead to the release of greenhouse gases, soil contamination, and water pollution (Talib *et al*., 2018).

- Electronic Waste (E-waste)

electronic waste refers to discarded electronic devices such as computers, smartphones, televisions, and appliances. The rapid advancement of technology and frequent product obsolescence have resulted in a significant surge in electronic waste generation (Ali *et al.,* 2020). electronic -waste contains hazardous materials such as lead, mercury, cadmium, and brominated flame retardants. Improper handling of e-waste can contaminate soil and water, posing risks to human health and ecosystems (Ma *et al*., 2018).

- Construction and Demolition Waste (C&D Waste)

Construction and demolition waste includes materials generated during construction, renovation, and demolition activities. This waste category comprises concrete, wood, metals, plastics, glass, and ceramics (Ongondo *et al.,* 2020). Improper disposal of C&D waste can result in land degradation, air pollution, and the depletion of natural resources. Effective management practices, such as recycling and reuse, can mitigate the environmental impact of C&D waste (Yang *et al.,* 2019).

- Hazardous Waste

Hazardous waste encompasses materials that exhibit characteristics such as toxicity, flammability, corrosiveness, or reactivity. It includes various substances like chemicals, solvents, pesticides, batteries, and medical waste. Inadequate treatment and disposal of hazardous waste can contaminate soil, water bodies, and air, posing severe risks to human health and ecosystems (Oladokun *et al.,* 2018). Strict regulations and proper waste management protocols are crucial to minimize the environmental impact of hazardous waste.

- Agricultural Waste

Agricultural waste consists of organic materials generated from farming, livestock rearing, and food processing activities. This waste category includes crop residues, animal manure, and agrochemical containers. When agricultural waste is not properly managed, it can lead to soil degradation, water pollution, and emission of greenhouse gases (Kaur *et al.,* 2019). Implementing sustainable practices such as composting and anaerobic digestion can help mitigate the negative environmental effects of agricultural waste.

- Methods for waste management

Effective waste management is crucial for mitigating environmental pollution, conserving resources, and promoting sustainable development. With the increasing volume of waste generated globally, it is imperative to identify and implement the best methods for waste management. By examining various approaches, including waste reduction, recycling, waste-to-energy conversion, and landfill management, we can gain insights into the best practices for sustainable waste management.

- Waste Reduction

Waste reduction, also known as source reduction or waste minimization, focuses on preventing waste generation at the source. It involves strategies such as product redesign, packaging optimization, and promoting sustainable consumption patterns. By reducing waste generation, this approach minimizes the need for waste management infrastructure and associated environmental impacts (Papargyropoulou *et al*., 2019). Waste reduction strategies have been successful in various sectors, including manufacturing, retail, and hospitality.

- Recycling

Recycling is a widely recognized waste management method that involves the collection, sorting, and processing of waste materials to produce new products or raw materials. Recycling conserves natural resources, reduces energy consumption, and mitigates the environmental impact of waste disposal (Zhao *et al.,* 2020). Advances in recycling technologies have expanded the range of materials that can be recycled, including plastics, paper, glass, and metals. Effective recycling programs require infrastructure, public participation, and market demand for recycled materials (Geng *et al*., 2018).

- Waste-to-Energy Conversion

Waste-to-energy (WTE) conversion technologies aim to recover energy from waste through processes such as incineration, gasification, and anaerobic digestion.

These technologies generate heat or electricity, reducing reliance on fossil fuels and mitigating greenhouse gas emissions (Liu *et al.*, 2019). Waste-to-energy facilities often incorporate pollution control measures to minimize air emissions and ensure safe waste disposal. However, concerns regarding air pollution, ash disposal, and potential conflicts with recycling efforts must be addressed for optimal waste management (Zhang *et al.*, 2021).

- Landfill Management

Landfills remain a significant component of waste management, particularly for non-recyclable and non-combustible waste. Effective landfill management practices aim to minimize environmental risks through proper site selection, engineering design, and post-closure care. Modern landfill designs incorporate liners, leachate collection systems, and gas capture mechanisms to reduce groundwater contamination and methane emissions (Wang *et al.*, 2018). Landfill mining and reclamation techniques also offer opportunities for resource recovery from existing landfills.

- Integrated Waste Management

Integrated waste management (IWM) emphasizes a holistic and comprehensive approach to waste management, combining multiple methods to optimize resource recovery and environmental protection. Integrated waste management considers waste reduction, recycling, composting, energy recovery, and landfilling as complementary components within a broader waste management framework (Cheng *et al.*, 2020). By integrating various strategies, Integrated waste management maximizes waste diversion, minimizes environmental impacts, and promotes circular economy principles.

- Rationale for Implementing Waste-to-Energy Technology:

The implementation of waste-to-energy technologies presents a promising solution to address the environmental and economic problems associated with waste management. By converting waste into usable forms of energy, such as electricity, heat, or biofuels, waste-to-energy technologies offer numerous benefits such as;

- Environmental Benefits:

Waste-to-energy technologies divert significant amounts of waste from landfills, thereby reducing the need for expanding landfills and minimizing the associated environmental risks. Waste-to-energy processes also help mitigate greenhouse gas emissions by capturing methane produced from decomposing waste, thus contributing to climate change mitigation.

Waste-to-energy technologies facilitate the recovery of valuable resources from waste streams, promoting resource conservation and the transition to a circular economy.

- Economic Benefits:

Waste-to-energy technologies provide a renewable source of energy, reducing dependence on fossil fuels and stabilizing energy prices. Additionally, they offer potential cost savings by offsetting expenses related to landfilling, waste transportation, and resource extraction.

The implementation of waste-to-energy projects requires a skilled workforce for construction, operation, and maintenance, leading to job creation. Furthermore, the development of the waste-to-energy sector attracts investments, stimulates local businesses, and promotes technological innovation, fostering overall economic growth.

III. RESEARCH METHOD

Laboratory research method was used in the study. The laboratory research method is a scientific approach used to conduct controlled experiments and investigations in a controlled environment known as a laboratory. It involves systematic and controlled manipulation of variables to study their effects and understand cause-and-effect relationships. Laboratory research allows researchers to control and manipulate various factors to isolate and examine specific phenomena or hypotheses.

- Research reagents and Equipment’s

The reagents and equipment’s incudes, Anaerobic Digester, Incubator, Gas Chromatograph, Biomass dryer, Reactor, Mass Spectrometer, Gas Analyzer, Centrifuge, thermal Oxidizer ,Energy Generator and distill water.

- Experimental Procedure

In the experimental procedure, the method Smith,*et al*,(2018) was used as follows;

- Waste Collection and Sorting :A representative sample of waste materials, including organic waste (food waste, agricultural waste, etc.) and other suitable waste streams were collected and Sorted out into different categories based on their composition and characteristics. This is done to ensures a homogeneous waste feedstock for subsequent processing.

- Waste Pre-treatment: Depending on the waste type appropriate pre-treatment techniques was used to enhance the conversion process. This include shredding, grinding, and drying the waste materials.

- Waste Conversion: Each type of waste, suitable conversion method was used. Method of conversion used were

a. Anaerobic Digestion: A controlled anaerobic environment was used to decompose the organic waste into producing biogas, primarily composed of methane.
b. Pyrolysis: the waste materials was heated in the absence of oxygen to convert them into a combustible gas (syngas), biochar, and bio-oil.
c. Gasification: Here waste was converted into a gaseous fuel (syngas) by reacting it with a controlled amount of oxygen and steam.
d. Incineration: The waste materials are heated at high temperatures to produce heat which can be used to generate steam and subsequently electricity through a steam turbine.

IV. RESULT

The finding of the study showed that there a various forms of waste products such as organic waste (food waste, agricultural waste, etc.) and others. These waste products have the capacity of causing serious damage to the environment when not properly disposed and it can be so difficult to manage them. This finding agree with the finding of Ongondo *et al.,* (2020) who in his study noted that there are various waste category comprising of concrete, wood, metals, plastics, glass, and ceramics. Result also indicated that there are various ways to convert waste material into useful resources that can be re-used . some of these, is the conversion of waste into energy. However, the conversion method of waste is dependent on the type of waste to be converted. Some of the conversion type include incineration which gives out heat that can be used to drive turbine, others are gasification, Anaerobic Digestion and Pyrolysis. All these methods have been found to be effective in the conversion and management of waste. This study finding corroborate with the finding of Cheng *et al.,* (2020) who in his study reported that integrated waste management help in waste reduction, recycling, composting, energy recovery, and landfilling as complementary components within a broader waste management framework. The study finding also is in consonance with the finding of Wang *et al.,* (2018) who said that effective landfill management practices aim to minimize environmental risks through proper site selection, engineering design, and post-closure care which help to reduce groundwater contamination and methane emissions.

However, the study further showed that the most effective waste management and also cost effective is Pyrolysis waste management and anaerobic digestion waste management which involve the use of anaerobic bacteria in digesting waste and at the same time convert the waste to energy that can be used for household cooking and for electricity generation.

CONCLUSION

The implementation of waste-to-energy technologies brings forth numerous environmental and economic benefits. By reducing landfill waste, mitigating greenhouse gas emissions, and promoting resource recovery, waste-to-energy technologies play a vital role in sustainable waste management. Additionally, these technologies contribute to energy generation, cost savings, job creation, and economic growth. As society continues to grapple with waste management challenges, the adoption of waste-to-energy technologies offers a promising solution for a greener and more sustainable future.

RECOMMENDATION

Based on the finding of the study, it is recommended that both government and the society should utilize Pyrolysis and anaerobic digestion method of waste management which is the most effective and cost effective method of waste management system in managing their menace of waste.

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