Biogas – Sustainable Energy for Rural Villages in Zambia

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Abstract

Access to reliable energy is a major challenge for developing countries where large rural populations rely on subsistence farming and cook their food over traditional wood-burning stoves or open fires. Cooking with wood-burning stoves is also a significant health hazard, causing illness and death due to continuous smoke and particulate inhalation. Biogas energy from the decomposition of organic matter in an oxygen-free environment (anaerobic digestion) offers a clean-burning alternative, much like propane or natural gas. Common feedstocks for anaerobic digestion include livestock manure, food waste and crop residues. The objective of this study was to assess the current and future potential for biogas energy in Zambia, where the electric-power grid serves only four percent of the 10.4 million mostly rural population. The impact of biogas technology was analyzed in the context of energy use, deforestation, social and climate change effects. The study indicates that biogas production in Zambia has the potential to provide clean energy in rural/remote areas, minimize deforestation, improve health and environmental conditions, and decrease greenhouse gas emissions. To realize these benefits, however, policies are needed to create a market for bioenergy, transfer knowledge from experts to villagers, and promote the use of local materials for digester construction.

Introduction

- Biogas is a relatively simple and efficient technology that could truly transform Zambia, a mostly rural nation.
- Over half of this developing country relies on natural resources for survival, meaning they are likely subsistence farmers who cook over a traditional wood-burning stove.
- Worldwide, wood-burning stoves are linked to around 3 million deaths every year (Hamid and Blanchard, 2018) due to smoke and particulate inhalation.
- Biogas has the potential to greatly reduce the mortality linked to traditional stoves and create a movement of development in Zambia.
- If biogas is to contribute to Zambia's development, it must align with the United Nations' sustainable development goals for providing affordable and clean energy, protecting our forests, empowering women and educating children, and climate action (UN, 2023).

Figure 1: *A women in Zambia cooking on a traditional wood-burning fire (Jagoe et al., 2020).*

Objectives

- Assess the current and future potential for biogas energy in Zambia.
- Question: Is biogas a suitable fit for development in remote villages, and can it have a sustainable future?

Methods

- Conduct a literature review to explore the state of biogas in Zambia.
- Detail the current situation based on all of the relevant factors.
- Collect data to explore the impact biogas technology can create on a social, political, and environmental level.

Results

Energy

- Biogas energy is the methane generated during the decomposition of organic waste in an anaerobic environment (Wilkie, 2005, 2008).
- Anything from animal manure, human waste, cull crops, spoiled food, weeds, or animal carcasses could be used in an anaerobic digestor (Wilkie, 2016).
- Biogas burns clean and can be used much like propane or natural gas for cooking, heating, and electricity.
- Rural villagers rely on fire not only for cooking but for light and heat as well, which increases the amount of smoke they inhale.
- Biogas would best be used for powering a simple stove, or even a gas lantern, but could advance into generating electricity as knowledge and capability of the technology in a village grows.
- 1306 GWh energy could be produced every year if biogas was utilized in Africa (Rupf *et al.*, 2016).

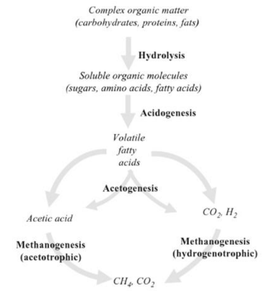

Figure 2: *The steps involved in anaerobic digestion.*

Figure 3: *Biogas flame.*

Deforestation

- Biomass is heavily relied on as a fuel in Zambia. This includes firewood, charcoal, and manure.
- 88% of rural Zambians use wood for cooking (Kaoma and Gheewala, 2021).
- On average, 250,000 to 300,000 hectares of forest are lost per year (Vinya *et al.*, 2011).
- Charcoal production also contributes to deforestation and increased health problems.

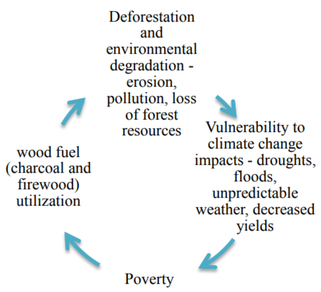

Figure 4: *The cycle between poverty and land degradation (Makai and Molinas, 2013).*

Social

- Wood fuel consumption is directly linked to an increase in poverty, poor environmental sustainability, and gender equity (Makai and Molinas, 2013).
- Women and children can spend up to three hours a day gathering firewood (Shane and Gheewala, 2017). Women could use this time to create value-added products, farm, or take goods to market. Children would have the opportunity to attend school or further their studies.
- By utilizing existing waste (livestock manure, food scraps), biogas eliminates the need for wood stoves, thus reducing smoke-related illness and increasing the social standing of women and children.

Greenhouse Gases

- Practices such as poor manure management, burning wood fuel and crop/forest residues, fertilizer production, and poor fertilizer application lead to increased greenhouse gases.
- A beneficial by-product of anaerobic digestion is the organic fertilizer that comes from the output.
- Using this organic fertilizer promotes soil restoration as a healthy microbiome is reintroduced.
- By providing the knowledge for manure and crop residue management through using anaerobic digestion and providing a fertilizer by-product and biogas fuel for cooking, greenhouse gases could be greatly reduced.

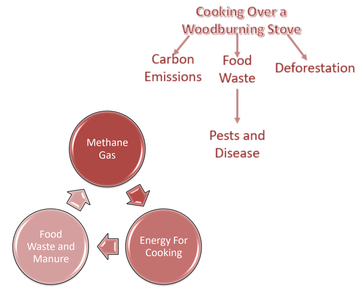

Figure 5: *Traditional wood-burning cooking versus the closed cycle of biodigestion.*

- Biogas has the potential to avoid 2357 Gg CO_2 eq. if it was fully embraced in Zambia.
- Chemical fertilizers could be reduced by 76%, if this technology was adopted (Shane and Gheewala, 2017).

Conclusions

- Biodigestion is a holistic technology, which has massive potential to spur growth and development in third-world nations like Zambia.
- Based on the literature review, biogas technology can meet the energy needs of rural Zambians, while greatly reducing the environmental and social impact of traditional fuel sources.
- Despite the benefits available from bioenergy, there have been many missed opportunities in Zambia, including government policy and lack of education. However, there still exists a large opportunity to invest in locals and communities to stir a grassroots movement to establish biogas in rural villages.

Figure 6: *Biodigestor at UF's BioEnergy and Sustainable Technology Laboratory.*

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