Biogas Energy for Remote 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. Women and children spend hours collecting the firewood needed for cooking, limiting time available for school/education or engaging in productive economic activities. 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 that can be used 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 see the fullness of 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

Zambia is a land full of opportunity and natural resources. Biogas is an easy and efficient technology that could truly transform this nation, especially the rural areas. As of 2004, Zambia had around 10.4 million people. 64% of these citizens are actively involved in agriculture (FAO, 2005). 54% of Zambia is rural (Abeygunawardena, 2003). 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. As people who live directly off the land, they are the most susceptible to the effects of climate change. Challenges will increase for access to clean drinking water, a decrease in crop yields, and an increase in pests and disease (Abeygunawardena, 2003). Furthermore, there is a direct link between wood consumption and poverty. Collecting wood can take up to 3 hours a day, with an additional one hour of cooking (Makai and Molinas, 2013). This limits the time that could be spent on creating value-added products, going to the market to sell goods, or even furthering education. 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.

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

Objective

- Assess the current and future potential for biogas energy in Zambia.
- The question posed is this: *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 not only on biogas but explore the impact biogas technology can create on a social, political, and environmental level.
- If biogas is to be used 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).

Results

Biogas energy is the methane generated during the decomposition of organic waste in an anaerobic environment (Wilkie, 2005, 2008). Biogas burns clean and can be used much like propane or natural gas. There are a large variety of inputs to generate this energy. Anything from animal manure, human waste, cull crops, spoiled food, weeds, or animal carcasses could be used in an anaerobic digestor (Wilkie, 2016).

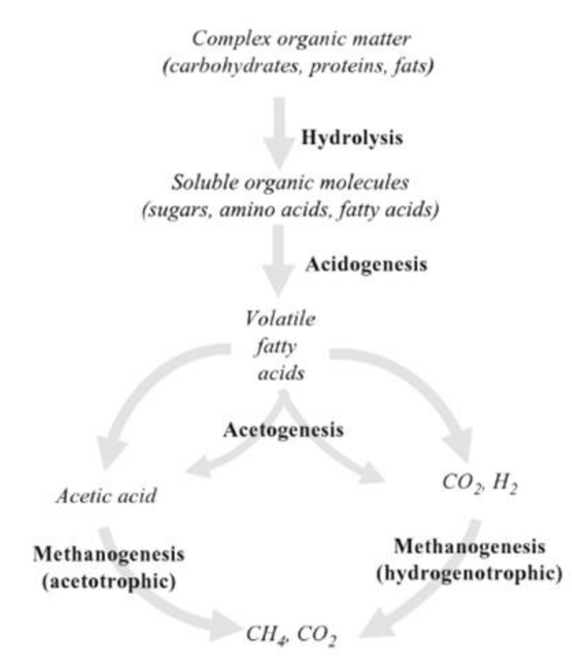

Figure 2: *The steps involved in anaerobic digestion.*

Energy

Zambia's government-run, gridlocked power system is only available to 4% of the population. The other electricity alternative is solar panels, which are only available to 7.4% of the rural population (Kaoma and Gheewala, 2021). Thus, villages must rely on fire for not only cooking but light and heat as well. The average amount of time individuals use a wood-burning fire is longer, which also increases the amount of smoke they inhale.

Biogas has the potential to produce energy for cooking, heating, electricity, and even vehicle fuel (Wilkie, 2016). 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. Studies have shown that a potential of 1306 GWh energy could be produced every year if biogas was utilized in Africa (Rupf et al., 2016).

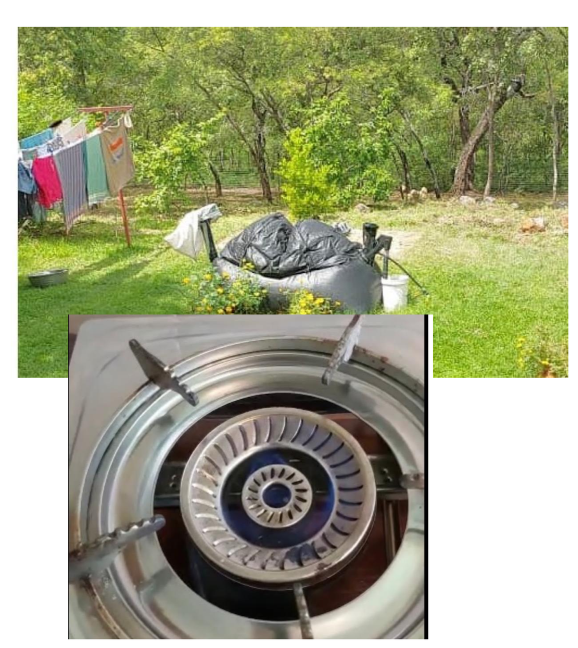

Figure 3: *A Homebiogas unit outside an expat's house, and the blue flame produced on the stove.*

Deforestation

Biomass is heavily relied on as a fuel. This includes firewood, charcoal, and manure. Every year in Zambia, 1-5Pg of carbon is burned from biomass (Shane et al., 2016). 80% of Zambians depend on wood for cooking (Makai and Molinas, 2013). 88% of rural Zambians use wood for cooking (Kaoma and Gheewala, 2021). Less than 1% of urban Zambians utilize propane or kerosene (Tembo et al., 2015). With such a heavy dependence on wood, Zambia has some of the highest deforestation rates, ranking amongst the top 17 countries (Chidumayo and Gumbo, 2013). On average, 250,000 to 300,000 hectares of forest are lost per year (Vinya et al., 2011).

By utilizing existing waste, biogas eliminates the need for wood stoves. Bioenergy acts as a closed system within the life of a rural Zambian. Every day they cook, thus producing food scraps. Livestock is a common occurrence, and their natural by-product is manure.

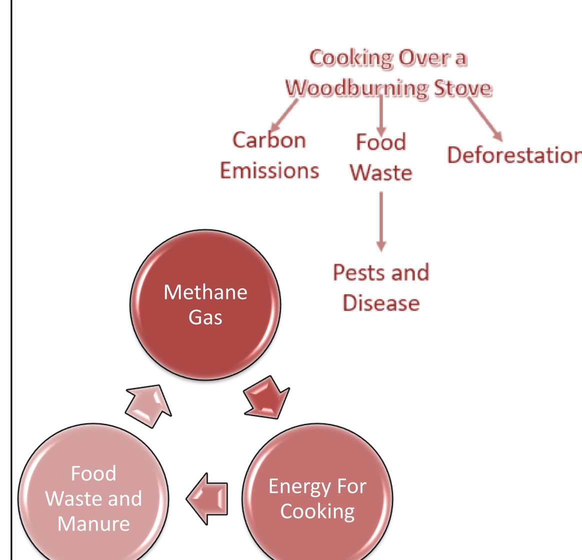

Figure 4: *Traditional wood-burning cooking versus the closed cycle of biodigestion.*

Social

An increase in wood fuel consumption is directly linked to an increase in poverty, poor environmental sustainability, and gender equity (Makai and Molinas, 2013). Women and children are often responsible for tending to household chores. This includes cooking and collecting firewood. On average, they spend three hours a day gathering wood (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 a school or further their studies. In Zambia, an individual's free time is commonly used to find temporary work. This money is often used to buy charcoal, especially in urban areas. In 2007, the charcoal industry in the capital city of Lusaka generated around $28.8 million (Makai and Molinas, 2013).

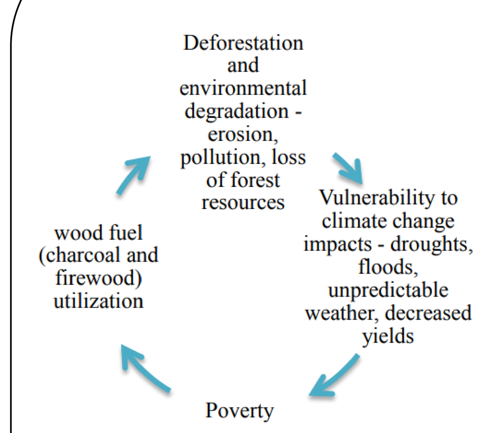

Figure 2: *The cycle between poverty and land degradation (Makai and Molinas, 2013).*

Charcoal production also contributes to deforestation and increased health problems for women who tend to be involved in its creation. The production of charcoal is also highly inefficient, with a loss of 75-80% of its energy (Richardson et al., 2021). Adding a chimney to a traditional kiln is just one way to make the process more efficient (UN, 2019). However, moving away from reliance on charcoal would be the most beneficial.

Greenhouse Gas

Marginalized individuals who live off the land are the most likely to be affected by climate change. Droughts and flooding due to temperature increase impact crop yields. 90% of Zambia's farmers are subsistence, meaning a decreased crop yield can devastate their families (ITA, 2022). This pressure has led to poor farming practices, and an increased amount of fertilizer to try and boost yields (Richardson et al., 2021). Practices such as poor manure management, burning wood fuel and forest residues, burning crop residues, fertilizer production, and poor fertilizer application only lead to increased greenhouse gases.

Biogas has the potential to avoid 2357 Gg CO_2 eq. if it was fully embraced in Zambia. A beneficial by-product of anaerobic digestion is the organic fertilizer that comes from the output. Chemical fertilizers could be reduced by 76% if this technology was adopted (Shane and Gheewala, 2017). Not only would this reduce the greenhouse gas emissions from fertilizer production, but it would increase land quality and save villagers money. 4kg of an NPK fertilizer costs about $11 in Zambia. An unskilled worker in Zambia makes around $96 a month, while the average individual makes $126 (Trading Economics, 2017). There is a limited amount of purchasing potential with this income, so everything needs to be used wisely.

By using this organic fertilizer, there will be soil restoration as a healthy microbiome is reintroduced. The longer the land produces a high yield, the less likely deforestation will occur to clear another plot of land (Richardson et al., 2021). Both crop residues and livestock manure would be used in a digester, reducing their gas emissions. By providing the knowledge for manure and crop residue management through using anaerobic digestion, and providing a fertilizer by-product and fuel to cook over, greenhouse gases could be greatly reduced.

Conclusions

Biogas has massive potential in developing nations like Zambia. Based on the literature review, bioenergy technology can meet the needs of rural Zambians, while greatly reducing the environmental and social impact of traditional energy sources.

It is a holistic technology, which can spur growth in third-world nations. Despite the benefits available from bioenergy, there have been reasons why the technology has yet to be applied. There are 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 3: *Caitlyn Claverie and Dr. Ann Wilkie next to the biodigestor at UF's BioEnergy and Sustainable Technology Laboratory.*

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