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Opportunities and Barriers to Biogas Adoption in Malawi

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Abstract: Malawi has the potential to explore the utilization of biogas technology. The technology has existed in the country for decades. However, the uptake has been lower than expected. Further, there has been a high rate of dis-adoption of the installed systems. To deal with the problem, this study explored the opportunities and barriers to biogas technology to enhance biogas adoption and utilization in Malawi. Qualitative research methods using key informant interviews were employed to collect the data from biogas adopters, dis-adopters, potential adopters, and experts. A total of 22 households and 6 experts were interviewed. The findings of the study show that the country has opportunities for biogas adoption and utilization. The most mentioned opportunities were livestock farming practices, constraints to access to reliable energy sources, associated benefits of biogas technology, and land holding. However, the adoption of the technology has faced several challenges. Commonly cited barriers were the high installation and maintenance costs, inadequate feedstock, inappropriate dissemination approaches, lack of training after installation services and expertise, lack of reliable water sources, absence of ownership, lack of cooperation amongst institutions involved in biogas promotion, lack of a coordinating body for institutions involved in biogas dissemination, lack of standards, and socio-cultural factors. To overcome the challenges, strategies were identified, and these include the provision of incentives, loans and subsidies, provision of technical support services, having demonstration sites, employing suitable dissemination approaches, co-digestion or diversification of raw materials, awareness campaigns, and collaboration amongst sectors involved in biogas dissemination.

Keywords: adoption; barriers; biogas; dissemination; opportunities

Citation: Kulugomba, R.; Mapoma, H.W.T.; Gamula, G.; Blanchard, R.; Mlatho, S. Opportunities and Barriers to Biogas Adoption in Malawi. *Energies* **2024**, *17*, 2591. https://doi.org/10.3390/en17112591

Academic Editor: Ronghou Liu

Received: 2 June 2023
Revised: 6 July 2023
Accepted: 10 July 2023
Published: 28 May 2024

1. Introduction

Energy is the driving force behind commercial growth and plays a crucial role in the social and economic progress of all countries [1]. The world was affected by a deadly coronavirus disease in 2019 (COVID-19), which impacted the global energy demand. During the pandemic, world energy demand decreased by 5% due to the closure and extended lockdowns of industries and day-to-day operations [2]. Reduced energy demand and consumption led to a decline in the rate of carbon dioxide emissions [3]. Before the epidemic, carbon emissions had increased by 1% annually over the last few decades [4]. When COVID-19 first hit the world in late December 2019, Green Houses Gases (GHGs) and carbon emission rates dropped by 7% and 17%, respectively [3]. However, after pandemic restrictions were lifted, emissions began to rise because of the recovery in energy demand and economic activity [3]. Looking at the situation positively, the current situation provides

chances for governments to increase the utilization of green energy [5]. Biogas, as a renewable energy source, can produce energy, reduce carbon dioxide emissions, and combat waste problems [6]. The utilization of biogas has the potential to achieve 10 of the 17 Sustainable Development Goals (SDGs), namely: no poverty (goal 1), zero hunger (goal 2), good health and wellbeing (goal 3), affordable and clean energy (goal 7), decent work and economic growth (goal 8), industry, innovation, and infrastructure (goal 9), sustainable cities and community (goal 11), responsible consumption and production (goal 12), climate action (goal 13), and life on land (goal 15) [6].

Biogas technology could be a solution for Malawi, as the country has limited access to electricity, with only 10% of the population having access and 97% of people depending on biomass in the form of charcoal and firewood [7,8]. Excessive reliance on unsustainable biomass use has several impacts on the environment, health, and deforestation [2]. It has been reported that pneumonia, caused by smoke from charcoal and firewood, is the leading cause of death for children under the age of five in Malawi. It is also one of the main reasons for morbidity [9]. It is further estimated that about 300 out of every 1000 children under 5 years of age suffer from pneumonia [9]. The impact of the use of charcoal and fuel wood on deforestation and the environment in Malawi is so significant that it has been predicted that Malawi will not have enough trees beyond 2030 to meet the charcoal and firewood demand of the population, hence causing the prices of charcoal and wood to soar [7].

The Government of Malawi's 2018 national energy policy aims to provide all Malawians with access to affordable, reliable, sustainable, efficient, and modern energy by 2030 [9]. The policy has identified biogas as a major alternative to firewood for cooking and heating [9]. According to the policy, the government intends to roll out biogas pilot projects in four districts where there is a high rate of deforestation and where the cost of biomass is very high. These projects will be operated for three years and then biogas plants will be installed in two peri-urban districts per year. The government's plan can be easily achieved as the country has 56,148,676 livestock, having the potential to produce dung amounting 7,960,267 tons per annum for biogas production.

The technology has been utilized as an alternative source of energy in rural areas of Malawi [10]. Since its inception in the country, there have been many initiatives proposed by the Government, individuals, and private sector to promote the technology, as indicated in Table 1 below [11]. However, more digetsers have been set up by private institutions in the country, which are not documented.

Table 1. Name of institutions involved in biogas dissemination in Malawi [1].

Name of the Institutions	Type of Digester Promoted	Number of Systems Installed	Location (Districts)
Mzuzu University	Fixed dome	21	Mzuzu
Ecogene	Homebiogas model, Sistema	92	Lilongwe
Green impact Technologies	Sistema	4	Lilongwe
Ministry of Energy	FlexiTarpaulin biogas digester	72	Lilongwe
Intrinsic biogas	FlexiTarpaulin biogas digester	145	Blantyre
Community Energy	Sistema	9	Lilongwe

[1] Data above were provided by officers working with the respective institutions.

Biogas technology, like many other renewable energy technologies, has not taken off as expected in the country [7]. However, other African countries, such as Kenya, Uganda, Ethiopia, Tanzania, Rwanda, Cameroon, Burkina Faso, and Benin, have profited from the technology [12]. Some of these countries border Malawi and have the same tropical climate conditions as Malawi, suggesting it may be appropriate for biogas technology. Climatic conditions are an important factor affecting biogas adoption [13]. However, there is insufficient information in the literature regarding barriers preventing the adoption of the technology in the country. The study was, therefore, deployed to identify factors preventing the widespread use of the technology. Failure to identify barriers in developing countries can make stakeholders criticize each other for the technology dissemination

failure [14]. The study was specifically aimed at identifying opportunities available in the country, which can assist in the dissemination of the technology. Identifying barriers and opportunities offers valuable information to decision makers to develop policies for the successful adoption of biogas technology in Malawi. The study further added knowledge to the inadequate literature on the key opportunities of and barriers to biogas adoption in the country.

2. Materials and Methods

The study identified fifteen (15) Government districts in Malawi with functional and non-functional biogas technologies from the companies involved in installation of biogas systems. From the identified districts, four (4) districts were randomly selected, namely Mchinji, Mzimba, Ntcheu, and Chikwawa (Figure 1). Within the selected districts, a list of households with biogas digesters was identified. A total of twenty-two (22) households were purposively selected from the list, and these included homes that were using biogas technology (adopters), households that had stopped using biogas technology (dis-adopters), and households that had never used biogas technology but have potential to adopt the technology (potential adopters). Purposive sampling was used to select six experts (6) to be part of the participants by deliberately selecting experts who were involved in installation of the systems.

Figure 1. Study areas. Source: Map of Malawi from D-maps (https://d-maps.com/carte.php?num_car=4781&lang=en, accessed on 1 June 2023).

The study employed a qualitative approach using semi-structured interviews. Before the interviews were conducted, ethical approval was sought from the National Commission for Science and Technology (NCST), and the request was approved. A semi-structured study guide was used for data collection. The guide contained questions about respondents' energy sources, resource availability, benefits, and barriers to biogas adoption and utilization. A mobile phone with voice-recording capability was used to record the respondents. All interviews for households were conducted in Chichewa, a native language of Malawi, and interviews for experts were carried out in English. The audio interviews were transcribed from audio into an easily analyzable format (text). The data were analyzed using a thematic approach, whereby themes or patterns were identified in qualitative data and were used to answer research questions [15]. NVivo 20 software was used for the analysis.

3. Results

3.1. Opportunities for Biogas Dissemination in Malawi

To determine the opportunities that existed in the country, the respondents were asked to mention challenges associated with the acquisition of reliable energy sources and benefits of using biogas technology. Further, the respondents were requested to mention livestock management practices used and the availability of land. The themes and codes for the opportunities are highlighted in Table 2 below.

Table 2. Opportunities for biogas dissemination in Malawi.

Theme	Sub Code	Extracted Code
Constraints to access to reliable energy sources	• I take about 3 h to collect firewood	Time consuming
	• Wood is now becoming scarce as more trees have been cut down.	Wood scarcity
	• I rarely use charcoal for cooking because it is expensive.	Expensive
Associated benefits of biogas technology over traditional energy sources	• Using biogas was time saving and you only need to collect dung.	Time saving
	• Less time spent on cooking, and it is easy.	Time saving and easy
	• My wife used to struggle to source firewood during rainy season but now it is convenient.	Convenient
	• Biogas is advantageous for my household as it eliminates the need to collect firewood.	Eased the burden of wood collection
	• Biogas helps protect the environment and manure enhances crop yield.	Environmentally friendly
	• Biogas can ease the burden of fuel wood collection and tree cutting.	Environmentally friendly
	• We achieved high maize yields using biogas manure, harvesting 3 tons on less than one acre of land due to its effectiveness.	Provision of fertilizer
Land holding	• I farm around 20 acres with my children.	Adequate land
Livestock farming practices	• Hybrid cattle are housed indoors, while local cattle roam freely.	Good livestock management

3.2. Barriers to Biogas Dissemination in Malawi

The respondents were requested to mention barriers that were hindering biogas adoption and utilization in Malawi. The themes that emerged from their responses were that biogas technology was expensive to install and maintain, biogas technology required adequate resources, such as dung, water, and labor, technical issues contributed to biogas failures, social norms and cultural, and poor dissemination methods used to promote biogas technology. The themes and codes for the barriers are highlighted in Table 3 below:

Table 3. Barriers to biogas dissemination in Malawi.

Theme	Sub Code	Extracted Code
Financial constraints	• The main challenge lies in the financial aspect of purchasing construction materials, particularly cement.	High cost of construction materials
	• We witnessed the installation process, including the excavation of a large hole that required a lot of labor.	High labor costs
Lack of ownership	• The technology was freely distributed to households, leading to a lack of ownership and appreciation.	Free distribution of biogas digesters
Technical challenges	• Water is not enough as we depend on a borehole built in 1957 which the whole village shares.	Inadequate water
	• The system halted because there wasn't enough livestock. We used to get dung from our neighbors, but now it is difficult to collect it for free from their kraals.	Lack of adequate animal dung
	• We are unable to find qualified experts in biogas technology, I am forced to teach them everything from the scratch.	Lack of technical expertise
	• The issue arose due to insufficient training on operating the digester for both the users and local artisans involved during the construction. No maintenance or repair guidance was provided.	Lack of sufficient training
	• I used biogas for 6 years but struggled to find assistance in fixing a broken pipe as the installation team did not provide after installation support.	Lack of monitoring
	• Biogas digester does not produce enough gas. It is not sufficient enough to serve the purpose.	Inadequate gas
	• There are no technical standards for biogas technology resulting in the installation of substandard systems.	Lack of standards
Socio-cultural factors	• My children think touching animal dung is disgusting.	Reluctance of people to touch dung
	• The negative perception of the community as others think that the use of biogas is very dangerous believing that it may cause fires and cancer.	Fear of biogas
	• The negative feeling of using gas produced from animal dung for cooking as it is considered dirty.	Negative attitude towards biogas
	• Women (especially those in the northern region) are not permitted in cow houses, due to traditional myths that they will prevent cows from giving birth to calves.	Refusal of women to enter cattle kraals
Lack of coordination among biogas agencies.	• The government's failure to bring all biogas experts together as it only works with selected few thereby creating a gap, especially with regard to access to the latest information.	Government's failure to bring biogas experts to work together
Lack of support from the Government	• I've engaged with the government before, but their feedback has been unsatisfactory.	Lack of governments commitment

4. Discussion and Recommendations

4.1. Opportunities of Biogas Technology

From the findings, it is clearly shown that biogas technology has the potential to be adopted in Malawi. The findings indicated that most respondents resided in rural areas with adequate land to install biogas technology and rear animals. According to [13], landholding was one of the factors that had a positive impact on the uptake of biogas. It has been mentioned that rural areas have more abundant space for setting up biogas plants than urban areas [13]. Having larger-sized land allows people to have enough space to feed and raise enough cattle to produce adequate dung. This is an opportunity that exists for biogas technology.

As indicated in the results, looking for energy sources for cooking was a widespread problem. Constraints to having access to reliable energy sources provide an opportunity for biogas technology to spread widely in the country. It was reported by [16] that there is a positive relationship between the distance from firewood sources and adoption of biogas technology. The current study observed that people spent a long-time collecting firewood. Shallo et al. [16] further discovered that as the distance to sources of firewood increases by 1 min, there is an increased possibility for biogas adoption technology by a factor of 1.02.

Another key component of biogas technology is the availability of animal dung. Having adequate animal dung depends on several factors and one of them is a livestock management system [17]. As alluded to in the findings, most respondents kept their animals indoors, and only local cattle were free range but kept overnight. The livestock management approach allows farmers to collect adequate dung. Livestock farming is practiced throughout Sub-Saharan Africa and offers enormous potential for biogas production from animal dung, particularly if the livestock is zero-grazed or kept overnight in livestock kraals, as is commonly practiced in countries, like Kenya, Malawi, South Sudan, Tanzania, and Uganda [18]. Malawi has the potential for producing biogas from livestock dung, with an estimated livestock population amounting 148 thousand [11], and over 8000 are smallholder dairy farmers with about 40,494 cattle; most of them were practicing zero grazing (DAHLD, 2010 cited by [19]). The livestock management system the country employs brings additional advantages to the dissemination of biogas technology. It has been observed that an inadequate supply of feedstock has been one of the obstacles hindering biogas technology uptake in rural areas [20].

Another essential element was that respondents were aware of the benefits of biogas technology and were willing to install the technology if given the opportunity (for those who did not have the technology). The associated benefits of biogas technology over traditional energy sources make it more attractive. Respondents were aware of the impact of the use of biomass on deforestation and how biogas technology is a viable alternative. Traditional energy sources have been related to increased negative consequences on the environment and health [21]. The study found that most people were aware of the consequences of using firewood and charcoal and were willing to switch to biogas technology as a viable alternative. To gain knowledge of biogas' existence, its associated benefits, and people's willingness to use alternative energy sources is an opportunity.

4.2. Barriers to Biogas Technology

It is evident from the findings that biogas dissemination faces several challenges. The most significant of all the barriers was related to the excessive cost of installation of a biogas system. The cost of the technology was too high for rural communities to afford who relied on farming to bring seasonal income and in a small amount. Most of the households visited had their systems installed either by the government or donors (most of the adopters only contributed bricks, sand, and cement). This finding indicates that subsidies play a crucial role in promoting biogas technology. Shahzad et al. [22] observed that the main underlying factor for the motivation of adopting biogas was due to subsidy. Hence, a lack of subsidies by donors or the government towards biogas promotion is one of the factors affecting biogas adoption in the country. This is similar to the findings from [17], who observed that

withdrawal of a subsidy by the promoting agencies in Kenya led to low adoption of biogas technology. Therefore, the provision of soft loans and subsidies is one way of overcoming the barrier. However, for the sake of ownership, it is important that subsidies and soft loans should only be given to those people who are aware of biogas technology and have an interest but do not have the financial means. Another option is to provide incentives to the private sector to manufacture locally imported biogas components. In doing that, prices of biogas digesters will be reduced, making the process affordable.

Further, from the findings presented earlier, most biogas dis-adopters lacked the necessary resources needed to produce biogas efficiently. To produce biogas, there is a need for adequate water for mixing with dung. A similar amount of water must be mixed with raw materials like cow dung before it is fed into a biogas digester, as the promoted digesters operate via wet anaerobic digestion [23]. Hence, for biogas technology to be successful, adequate water availability is a prerequisite. In addition to making a sustainable system, there is a need to have enough dung to feed the system. Biogas adopters and potential adopters should ensure that there is adequate feedstock available to sustain the system; otherwise, the system will collapse. This was the case with several biogas digesters that were visited. Most biogas digesters used cow dung as a feedstock. For one to qualify for the technology, ownership of two to three cattle was a prerequisite. However, most of the dis-adopters attributed inadequate dung (in terms of quantity) as one of the reasons for dis-adoption of biogas technology. In addition, it is necessary to explore other feedstocks apart from animal dung and explore the possibility for the co-digestion of dung with other substrates, such as food and vegetable wastes and lignocellulose wastes [12,24,25].

The findings clearly show that another driving force towards the dis-adoption of biogas systems was related to technical issues. Technical challenges have been known to be one of the factors leading to the dis-adoption of biogas technology in Africa [13,17,22,26]. It was observed that the beneficiaries of biogas technology were not given enough training on how to operate and maintain biogas digesters. It was discovered that most beneficiaries were given limited training in the operation of the system. However, no training was provided on the maintenance of the systems. Some systems were abandoned due to a lack of local artisans to provide maintenance services and a lack of spare parts. Biogas installers did not provide basic training on maintenance, even to the local artisans who were involved in the construction of biogas systems; as such, the artisans could not provide help when contacted by adopters. To make matters worse, the installers did not come back to monitor the systems after the installation. The findings explained that one of the reasons why beneficiaries were not trained and monitored was due to a lack of technical knowledge in the design, construction, installation, and maintenance of biogas technology. It was claimed by one of the experts that biogas technology is taught as a basic subject in colleges, and there is a need to introduce specialized in-depth training for experts. It was further mentioned that experts in biogas technology were rare and biogas companies were finding it difficult to employ qualified personnel. Previous studies have stated that there is a strong relationship between the availability of skilled technicians and the adoption of biogas technology [27]. Technical knowledge was identified as a critical factor in the uptake of biogas technology, and where these skills were utilized, there was a high adoption rate [28,29]. Bensah et al. [30] suggested that the widespread dissemination of biogas systems requires a pool of technical experts to provide quality installations and on-demand post-installation services. The introduction of specialized biogas technology courses in universities and technical colleges is one way to ensure the availability of experts in the field. Ali Siddiqui et al. [31] agreed that the accessibility of technicians demonstrates the uptake of biogas facilities and benefits farmers in some rural areas socially and economically. It was further proposed that local artisans should be made knowledgeable about biogas technology and competent enough to conduct maintenance on biogas systems once there is a problem and should be readily available at affordable prices [27]. In addition, biogas adopters should be furnished with basic training for them to be able to conduct minor repairs or maintenance.

Another technical issue was the lack of standards to guide the biogas industry. The lack of standards for biogas technology led to poor construction of biogas systems. Bensah et al. [30] stated that quality issues are critical to the success of a large-scale biogas scheme. It has been observed that poor biogas digesters often lead to the total failure of biogas systems and produce a negative attitude about the technology. Lwiza et al. [32] proposed that government agencies, in collaboration with Non-Governmental Organizations (NGOs) and private institutions involved in biogas dissemination, should develop standards for biogas digesters and end-user equipment. Quality control and standardization should also be extended to biogas equipment and pipeline-connecting materials and fittings [33]. The standards should be put in a manual, which must be adhered to by all companies involved in the promotion of biogas [30].

Another interesting factor was that all adopters had not completely replaced firewood and charcoal. The adopters commended the use of biogas technology and considered it very convenient; however, firewood usage remained an option. Some of the adopters had adequate gas to totally replace firewood but still used firewood. This only shows that people are sometimes resistant to change. Bonnke [17] observed that biogas technology was ranked the second main source of fuels after firewood. This situation has been observed to be common in Sub-Saharan Africa, where the use of multiple fuels has been a trend [34] and people are hesitant to move to more effective household alternatives [35]. It was surprising to discover that even though people regarded biogas highly and had seen observable benefits of its usage, they still tended to use firewood. This shows that there is a need for more education so that adopters should change their mindset regarding the use of firewood. Another explanation for the continuous use of firewood despite the installation of biogas technology was the insufficient gas that was provided by the technology. As indicated in the findings, some adopters complained that biogas was enough to cook most food, such as Nsima (Malawi staple food) and relish. This brought dissatisfaction, which led them to continue using firewood. This was also observed by [22], who stated that insufficient gas was one of the causes for the dis-adoption of biogas technology in Pakistan. Further, the study found that there was a misconception by some biogas users that food cooked using firewood and charcoal tasted better than with biogas. This observation is also in line with [22] findings that people dis-adopted biogas technology because the food cooked using biogas was not tasty.

The results have further shown that another drawback of the technology was due to the way it was disseminated in the country. Looking at the findings, the technology was mostly disseminated as demonstration plants. This dissemination approach of using pilot adopters as models to teach others plays an important role in the dissemination of any technology, as alluded to by the theory of diffusion of innovation [36]. The theory states that for a technology to be accepted, it should have observability. Some studies have found that having a demonstration of the performance of a technology before use can increase people's intention to adopt it [37–39]. However, this was not the case with the study areas. Despite having demonstration centers, the technology continued to face resistance. The study observed that most installers used a top-down approach, whereby the respondents did not express interest in having the technology. As such, most of the pilot systems were not functional. It is, therefore, important that the dissemination methods are in line with people's needs and demands. In addition, the technology was given to some beneficiaries for free and that brought in a lack of sense of ownership and value, and, due to that approach, the beneficiaries expected the installers to continue supporting them. The approach caused those who did not receive digesters to be reluctant to buy one as they too expected to be given one for free. The findings further showed that most systems that were installed as communal systems were not functional. One expert explained that the approach of having one digester for several people should not be encouraged as most people do not like working in groups as they do not trust each other. The respondent mentioned that this has been the case with several other initiatives in the study areas.

Other experts concurred with the idea that community-based biogas systems should not be encouraged as there were issues of who to feed the digesters, leading to system failure.

Social–cultural issues contributed to a high dis-adoption level of biogas technology. The use of animal dung produced mixed feelings. Most respondents stated that people were very reluctant (especially the youth) to touch animal dung as it was regarded as dirty, while others (old people) had no problem with the use of dung. It was further discovered that some people were scared to adopt biogas technology because it was considered dangerous and can burn their houses down and may cause cancer. In other areas, women were not allowed to enter cattle houses due to the cultural myth that when a woman enters the houses, the cattle will not be able to produce calves, so when a man was not available, the digesters were not fed, leading to total failure. Another social issue was that people were reluctant to adopt the technology as it was regarded as dirty. There is a need to conduct awareness and education campaigns to overcome social–cultural issues and share benefits of biogas technology. This is in line with [40] who recommended that communities be sensitized and educated on the use and benefit of biogas technology through simple languages. Zhou et al. [41] suggested that the government should assign a certain amount of money for providing knowledge of biogas operation and maintenance and conduct public lectures to stimulate people's interest in biogas technology. The government or Non-Governmental Organizations (NGOs) should establish demonstration sites where people can see how biogas systems operate. The establishment of demonstration centers where people can actually see how the biogas plant works can improve their understanding and help them decide [27]. The demonstration effect is a powerful driver of biogas uptake [42].

Finally, for biogas technology dissemination to be successful, there is a need to produce policies that can deliberately aim at accelerating the uptake of the technology. From the study results, there was no collaboration between the ministry responsible for energy and institutions involved in biogas dissemination. The study discovered that there are several biogas installers in the country who work independently and that the country lacks a body to coordinate and harmonize ideas for biogas promotion, apart from the Ministry of Energy, which provides policy guidelines. As such, it is important that the country should set up institutional structures for biogas dissemination so that all activities related to biogas are well-coordinated. Having a coordinating body will further assist in ensuring that quality biogas digesters are installed by producing standards. Bensah et al. [30] stated that quality issues are critical to the success of a large-scale biogas scheme. Lwiza et al. [32] proposed that government agencies, in collaboration with NGOs and private institutions involved in biogas dissemination, should come up with standards for biogas systems and end-user equipment. Control of quality and standards should also be ensured for biogas equipment and pipeline-connecting materials and fittings [33]. The standards should be put in a manual, which must be adhered to by all companies involved in the promotion of biogas [30].

5. Conclusions

Biogas technology has been available in Malawi for a decade; however, the uptake has been low. The study analyzed barriers that have hindered the adoption of biogas technology in the country. It has further identified opportunities that help in enhancing the acceleration of biogas technology. The study concluded that the country has a conducive environment for the dissemination of biogas, such as suitable climate, feedstock, land, and other factors, such as shortage of energy sources. Barriers include the lack of technical expertise, lack of adequate water, sociocultural factors, insufficient gas, mismatch between demand and supply, lack of financial support, high initial costs, and lack of monitoring of installed biogas systems. However, with the opportunities available, the technology can easily be disseminated by employing appropriate strategies, such as conducting awareness, provision of incentives and subsidies, capacity building for experts and local artisans and coordination of various sectors, development of biogas standards, setting up demonstration sites, producing deliberate policies to accelerate the dissemination, amongst other things.

Finally, there is a need to set up a coordinating institution that will bring together all players in the energy sector.

Author Contributions: Conceptualization, materials organizations, text preparation, writing and original draft preparation, R.K.; review, editing and supervision, H.W.T.M., G.G., R.B. and S.M. All authors have read and agreed to the published version of the manuscript.

Funding: The research received no external funding.

Institutional Review Board Statement: Malawi's National Commission for Science and Technology (NCST) approved the study and provided guidance on the conduct, which includes protection of the privacy of the interviewees.

Data Availability Statement: Data sharing not applicable.

Acknowledgments: The authors express their gratitude to the anonymous reviewers for their constructive suggestions. Regina Kulugomba is further grateful for the PhD scholarship support from the Government of Malawi and the Commonwealth Scholarship Commission in the UK.

Conflicts of Interest: The authors declare no conflict of interest.

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