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Evaluating Biogas Technology in South Africa: Awareness and Perceptions towards Adoption at Household Level in Limpopo Province

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Abstract

Despite the enormous advantages associated with biogas technology, the level of awareness and perceptions still remain very dismay. The level of adoption is relatively low compared to the potential of the technology. This chapter therefore aimed at unravelling the awareness and perceptions of the technology at household level in Limpopo Province of South Africa. In this study, 200 households were sampled; 72 households with biogas digesters and 128 without digesters. Primary data collection was elicited with the use of open- and closed-ended questionnaires. A non-parametric test of Spearman rank correlation coefficient and chi-square were employed to show the association between the variables. Empirically, the results revealed that income earned, cost of digester, lack of awareness programmes, water and feedstock availability, technical availability and assistance, and private sector participation are among the factors limiting the dissemination, awareness and perception of the technology in the province. The study recommends interventions through more elaborate awareness and promotion programmes in disseminating the technology as well as provision of technical assistance, loans, credits and subsidies to households willing to adopt the technology.

Keywords: energy, environment, digester, households, technology

1. Introduction

One critical issue confronting developing nations such as South Africa is the provision of sustainable energy, to a proportion of its population that do not have access to modern and reliable energy supply. Access to energy is viewed as a vital condition that enhances the development of a country's economic activities, in order for the people to have an improved quality of life [1]. This explains the notion why providing adequate, affordable, sustainable, clean and efficient energy remains the core interest of many countries. Despite the efforts in place to provide adequate, sustainable and modern energy, about 1.4 billion people worldwide do not have

access to modern energy carriers [2]. Sadly, the majority of the people without access to modern energy subsist in Africa, with a representation of 57% of the world population [3]. In South Africa, fossil fuel dominates the energy sector, with coal accounting for 89% and crude oil accounting for 22%, thus providing much of the energy consumed in the country [4]. In Limpopo Province, the energy carriers do not differ as the energy satisfaction in the province comes from coal and oil. Although the use of fossil fuel in generating energy brings an overwhelming burden to the environment in the form of greenhouse gas emissions, water contamination, air pollution and ecosystem degradation [5].

The Limpopo Department of Economic Development, Environment and Tourism (LEDET) identified biomass and solar as the main renewable resources of energy in the province [6]. The Department of Energy has developed a programme for attracting private investment into the energy sector. The Renewable Energy Independent Power Procurement programme (REIPP) has been designed to contribute towards the national target of 3725 MW of renewable energy and towards socio-economic and environmentally sustainable growth [7]. To meet energy demands in low-to-middle income households in many developing countries, the use of biogas technology is currently being deployed. The technology does not only provide energy but also serves as a good waste management measure [8]. Limpopo Province, like many other provinces in South Africa, has seen limited growth in the dissemination of biogas technology due to awareness and perceptions of the technology. Despite the long history of biogas technology in the country, the technology has witnessed poor growth of installed domestic biogas digesters, hence the initiation of this study.

2. Household energy sources and utilisation in Limpopo Province

The energy sector is central to South Africa's economy due to its reliance on energy-intensive, large-scale coal mining activities. Limited oil and natural gas reserves are present in the country; thus, the country relies and uses large deposits of its coal to meet most of the energy required, which is principally in the power sector. In 2013, less than 1% of the energy consumed was from renewable sources; 3% from natural gas; 22% from oil while 74% of the total consumed energy was primarily from coal and more than half was consumed in the electricity sector [9]. In 2017, South Africa was rated among the 10 top producers of coal in the world [10]. Due to its dependence on coal, the country is considered one of the continent's principal emitter of carbon dioxide, accounting for about 40% and thus placing the country as the thirteenth major emitter of carbon dioxide in the world [11]. Notwithstanding the renewable energy resources endowed in the country, there has been an energy shortage, which led to the energy crisis of 2008, which still persists till date [7].

A survey by the Department of Energy [4], with the aim of gathering information related to energy behaviour in South Africa households, indicated that there are significant differences between non-electrified and electrified households in Limpopo Province. To meet the basic energy needs, households employed an array of energy sources. Electrified households reported that they use electricity for heating, lighting or cooking. Even so, it is clear that other sources of energy, such as paraffin, fuelwood, gas and candle, are relied upon by at least a fifth of all the surveyed households with electricity. On the other hand, non-electrified households, in the absence of domestic connection primarily rely on fuelwood, candles, with additional households reporting using gas and coal. The use of renewable energy, such as solar was reported by a tenth of the electrified and non-electrified households

surveyed. A major factor that continues to play a significant role in domestic energy use is socio-economic differences. The use of paraffin, candles, and fuelwood was present in more than 70% of the households in the low-income bracket of less than R3000 monthly, while near-absence was almost recorded in the medium to high-income households [4]. Cooking is one of the utmost energy intensive applications in the households of Limpopo Province. Unsurprisingly, geographic variation indicated that Limpopo Province households have a lower share of electricity used for cooking purposes, which is less below the national average [4]. Although most households in the country rely on fuelwood as the second main source of energy for cooking, somewhat atypical is the case of Limpopo Province, where 44% (representing two-fifths of the households) use fuelwood as their main source of energy for cooking compared to 49% of the households using electricity for cooking [4]. Marginal share were reported for households using coal, solar electricity, gas and paraffin. In non-electrified households, paraffin and fuelwood dominate as the source of energy for cooking purposes, at 38 and 54%, respectively [4]. However, a small fraction of coal, gas, solar electricity and electricity from generators were recorded in small percentages of households as their primary sources of energy for their cooking needs. With the increases in paraffin prices, the findings are not too surprising, as fuelwood is an all-possibility compensation for the higher paraffin prices. However, the decrease in paraffin use is positive, but the increase in the use of fuelwood remains a great concern.

Domestic space heating is another intensive energy application in the households. Examination by electrification as the main source for space heating in electrified households indicated that 45% rely primarily on electricity, with a minority reporting paraffin, fuelwood and other sources of energy, at 4, 7 and 5%, respectively [4]. In non-electrified households in the province's households, fuelwood is primarily relied upon for space heating, accounting for 59%, while paraffin has a share of 11%, with other sources that consist mainly of coal stands at 5% [4]. In respect to water heating for bathing purposes, the most common electrical appliance used by electrified households in the province for water heating purposes is an electric geyser at 31%. Other appliances are the electric kettle at 23% or a combination of electric stove and kettle at 7% [4]. Conversely, in non-electrified households that rely on a single energy source for water heating, fuelwood exclusively accounts for 46%; about a quarter of the households also exclusively uses paraffin, which stands at 27 and 16% of the non-electrified households use a combination of paraffin and fuelwood [4]. The findings from the survey contend that there is a barrier in the province, which is hindering the switch to electricity as a preferred method for water heating for bathing purpose [6]. In terms of energy preferences and choice for heating water, other than for bathing purposes, the survey indicated that 93% of the households in the province, on average, depend on a single source of energy, while a small share of 5% is characterised by multiple sources. In electrified households, the use of electrical appliances for water heating, other than for bathing purposes, stands at 83%, while in non-electrified households, fuelwood exclusively accounts for 52% for the households, followed by paraffin, which is used by a further 38% of the households [4].

3. Research methodology

3.1 Description of the study area

Limpopo Province is the northern-most province of South Africa, lying within the curves of the great Limpopo River. It shares international borders with Botswana to the west, Zimbabwe to the north and to the east, Mozambique.

The province falls under the greater-savannah biome which is characterised by grassland and forest and it is sometimes referred to as the bushveld biomes. The bushveld, which comprises most part of the province, is renowned for cattle rearing. The vegetation types are of grave significance and need conservative representation in order to preserve the flora diversity, as over one-third of the forest has been reduced due to over-exploitation and utilisation of the forest resources [12]. Limpopo Province is viewed as one of the poorest provinces in the country, due to high unemployment rate that persist mostly in the rural parts of the province [13]. Most of the households in the rural parts which encompass much of the population depend on pension grants, government grants, and remittances from family members who migrate to other provinces to work. The household wealth is relatively lower, compared to other municipalities in South Africa [14].

3.2 Data collection and sampling methods

This study was centred on household survey conducted purposefully in Limpopo Province from 2018 to 2019. The province was specifically chosen because of the government promotion of pro-poor energy alternatives, transformation of organic waste-to-energy and other low carbon technologies in order to ensure energy provision and security. The primary data were elicited from respondents in the households using interviews and self-administered semi-structured open and closed-ended questionnaires. Secondary data for this study were gathered from unpublished and published research articles. For ease of understanding, the questionnaires and interviews were conducted in English language and where necessary, translated to XiTsonga or TshiVenda languages which are the local dialects of the respondents. Ethical considerations were strictly adhered to. The survey sample was drawn from households with and without biogas digesters. After an in-depth assessment of households with biogas digesters in the province, 72 households were purposively sampled, while 128 households without digesters were randomly sampled. From a household installed with biogas digester, at least one household without a digester was sampled randomly in order to elicit their opinion regarding whether a household with a digester influences their perception about the technology. The sampling technique could not be based completely on one sampling technique because in the study area, the number of households with biogas digesters were smaller, compared to households without digesters and thus the inference from the sample could not be drawn from one sampling type.

3.3 Data analysis

The generated data was analysed and simplified using Microsoft Excel spreadsheet and statistical procedures of the Statistical Package for the Social Sciences (SPSS 22.0). The data were coded, defined and labelled and fed in Microsoft Excel then, exported to the SPSS program, to generate descriptive statistics principally to identify patterns and trends. The results of the data were clearly displayed in simple pie chart, bar graph, and contingency tables. A non-parametric test of Pearson chi-square and Spearman rank correlation coefficient was also used to present a detailed analysis of the results.

4. Adoption challenges faced by biogas technology

The challenges faced by biogas technology in several developing countries including South Africa are numerous and has becloud the awareness and perception

as well as the potential of the technology. These factors have hindered the general dissemination of the technology. The rate of biogas technology dissemination is low, despite its potential, thus making the share of biogas technology in the energy mix very insignificant in many households, where it is supposed to play an alternative option in fuel substituting. For example, in South Africa, the numbers of installed digesters are around 700 with less than 100 in Limpopo Province [15]. The awareness and perceptions challenges faced by the technology include the following.

4.1 Dissemination of biogas technology

Another important factor which acts as a constraint to the adoption and dissemination of biogas technology is the awareness of the technology [16]. In Ghana, for example, lack of awareness about biogas technology was mentioned as one of the barriers in adopting the technology. Some cultural viewpoints such as stigmatising the utilisation of human excreta or even cow dung as substrate to biogas digesters, has the potential of discouraging its dissemination [17]. Thus, stories of successes and failures of previous biogas installations can also aid in promoting or constraining the dissemination of the technology. According to Gitonga [16], where an installed biogas digester performed well, word of mouth from the satisfied user will encourage other potential users to own the technology. In instances where the digester fails, it will create a negative dissemination impact on the technology; thus, discouraging potential adopters in the process. In Africa, success stories of biogas demonstration plants are relatively low. Many reasons are outlined for their failure. These include absence of energy focused policy, poor design, poor construction and material used, lack of maintenance from the owner, lack of project monitoring and follow-ups and poor ownership attitude and responsibility [17].

In addition, households evaluate the awareness attributes of modern energy carrier in their adoption decisions. Identified by Rogers [18] are five attributes that can accelerate or impede the adoption rate of the technology. These attributes are relative advantages, trialability, observability, complexity and compatibility. In the relative advantage of a modern energy carrier, the technology is evaluated in economic terms; according to its social status, satisfaction and convenience. A technology that is easily tried and experimented for its appropriateness with observable results to others is expected to be rapidly adopted than others. Furthermore, a compatible technology to existing cultural norms, values and experiences of a community has a better chance of adoption compared to any technology against such values and norms. In addition, a technology that is easy in understating and utilising is likely to be adopted quicker than those that require new skills, knowledge and understanding. According to Taherdoost [19], in the traditional adoption technology model, primarily, a consumer's adoption is determined by the 'perceived ease of use' and the 'perceived usefulness/benefits' of the technology. Therefore, in the process of making an informed decision to either reject or accept the new technology, the consumers weigh the option of the technology if it is easy to utilise (perceived ease of use) and if one's productivity will improve (perceived usefulness/benefits).

4.2 Biogas technology awareness

The study findings as presented in **Figure 1** indicated that 22% of the respondents acknowledged that they have at least heard about the technology with regards to financial implications. This implies that 22% of the households in the Province are aware about the existence of the technology. This can be attributed to the few biogas projects within their locality. The presence of the technology's existence in the study area however does not imply awareness of the technology. Awareness of

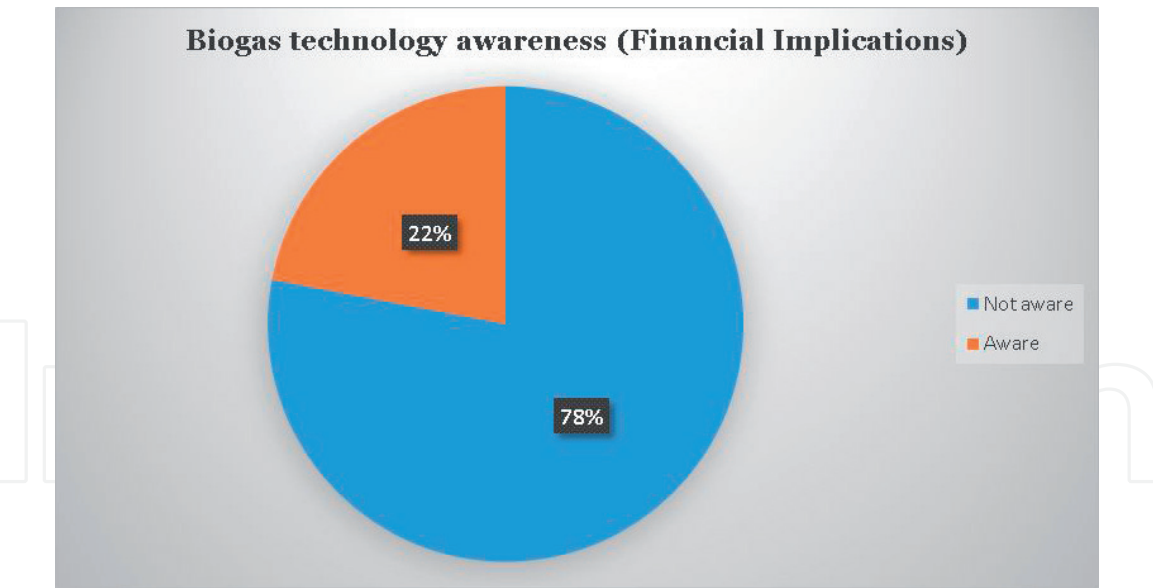


Figure 1.
Biogas technology awareness (financial implications) survey in the study area (source: field survey).

biogas technology involves households getting detailed information about the technology; from the functionality, financial implications and the numerous advantages the technology offers. The result further shows that 78% of the households have no relative idea about biogas technology in terms of the financial implications involved in respect to the technology. Further, the results (**Figure 2**) in terms of functionality, indicated that 66% of the respondents have no clue how the technology operates, while 34% revealed that they can operate the technology.

Technology awareness and perceptions are also disseminated via information channels. From the study as indicated in **Figure 3**, the identified channels of information that have helped in sensitising the households about the significances, advantages and efficiencies of biogas technology in the province include that from neighbours' with installed digesters, at 52%, and NGOs at 38%, which served as the main sources of information pertaining the technology. Others include 7% from government departments/agencies and 3% from media publications. This indicates that the role of government agencies and the media in disseminating the technology is very low. This can be improved through adequate education and dissemination, particularly in the rural areas, so that the social, economic and environmental benefits of the technology can be appreciated as against the continues use of fuelwood, which has detrimental effects on their health and wellbeing [20].

4.3 Biogas technology perceptions

From the field survey, the data obtained as shown in **Table 1** clearly indicated a prevalent perception of biogas technology at household level. The responses raised on the perceptions of the technology indicated that in households with biogas digesters, 91% agreed that biogas can help solve the problem of fuelwood for cooking, as agreed by 87% from the non-users. Regarding using the slurry from biogas to improve soil fertility, 88% of the users agreed, while 86% from the non-users also concurred. Using biogas technology as a method to manage waste in order to improve environmental hygiene was at 89% from the users. The respondents believed that it is a good management method compared to 88% from the non-users category. In the province, as part of their energy mix, most households still rely on fuelwood, which is harvested from the forest, thereby creating room for degradation, which can eventually lead to deforestation. In respect to biogas technology, 90% of the households

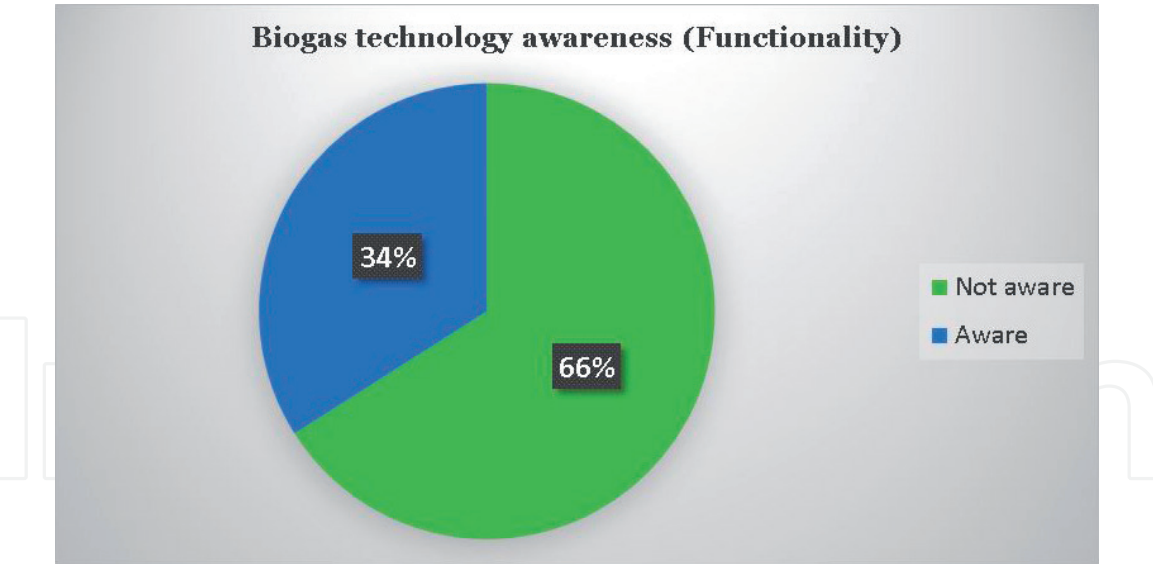


Figure 2.
Biogas technology awareness (functionality) survey in the study area (source: field survey).

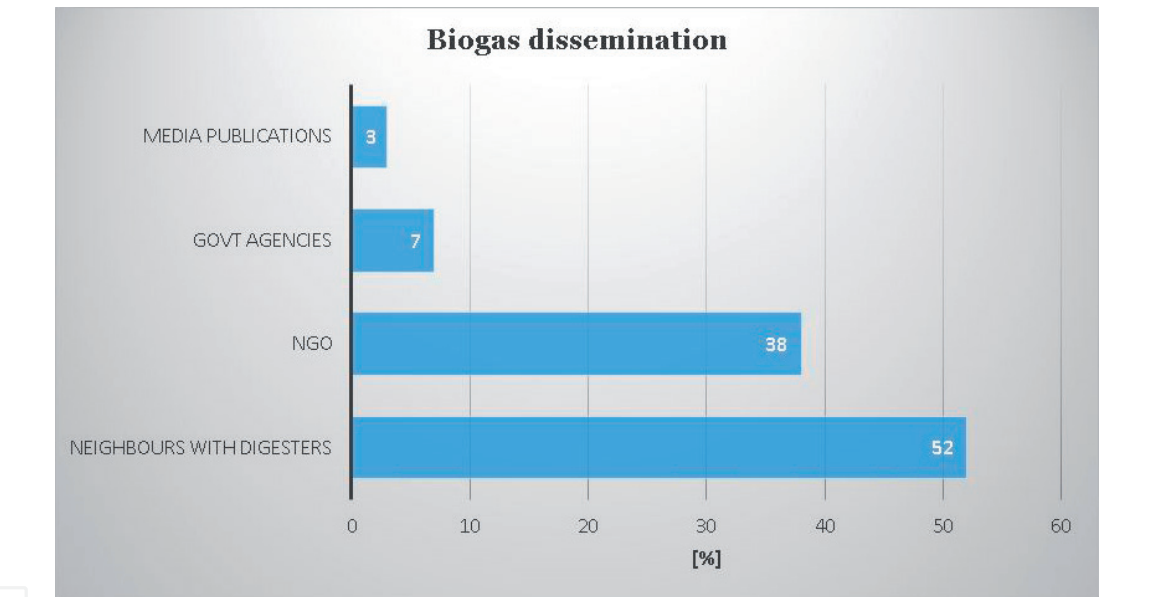


Figure 3.
Biogas dissemination in the study area (source: field survey).

using the technology have confidence that it can help reduce the rate of degradation and deforestation, while 75% from the non-users concurred to the statement. From the users and non-users, 96% from both clusters indicated that the use of biogas technology can help reduce the drudgery faced by women. On fuel consumption, compared to other cooking devices, 95% from the households using the technology agreed while from the non-users, 91% have the confidence that the technology will consume less fuel. On the general benefits of the technology, 89% from the users agreed that the benefits are worthy, while 82% from the non-users have confidence in the benefits of the technology. Further, the outcomes of the respondents were ranked and tested using Spearman rank correlation coefficient, to determine the significant correlation between the users and non-users of the technology. The Spearman rank results at $p < 0.05$, with a calculated value of 0.68, indicated that there is a positive and strong correlation in the perception of biogas technology among the users and non-users in the province. In essence, the more and better perception households have over biogas technology, the higher the chance of adopting the technology.

Statement	User (%)	Non-user (%)
Biogas can help solve the problem of fuelwood for cooking.	91	87
Biogas technology can help to improve soil fertility.	88	86
Biogas technology can improve hygiene due to the use of waste.	89	88
Biogas technology can reduce the rate of forest degradation and deforestation.	90	75
Biogas can relieve women's workload and save time used for fuelwood collection.	96	96
Biogas technology consumes less fuel than other conventional cooking devices.	95	91
Generally benefits of biogas technology over-weighs limitation/ weakness.	89	82

Source: field survey.

Table 1.
Biogas technology perceptions between user and non-user in the province.

4.4 Availability of water and feedstock

In Sub-Saharan Africa, one site-specific resource that has limited the scope of biogas technology is the availability of water that should serve to ensure effective operation of biogas technology. Studies by [21], suggest in their findings in Ethiopia that sources of water should be a walking distance of between 20 and 30 min from the household. Even in the circumstances where households own a satisfactory number of livestock, the system grazing nature, free grazing, semi-nomadic to nomadic have created problems in many parts of Sub-Sahara Africa in gathering feedstock to feed the digesters [22]. Poor supply of water has been reported as hindrance in the operation of biogas plants. For example, where there is adequate water supply, there is widespread adoption of the technology; mostly if the source of water is a short distance from the household or the supply is not altered by seasonal variation. Water shortages limit biogas operations as it is required in the mixture of the substrate before being fed into the digester [21]. Steady access to sufficient water supply is only available to small a percentage of the African region [23]. Sub-Sahara countries such as South Africa is considered as water-scare, water-stressed countries due to its climate aridity. Coupled with uneven distribution of rainfall throughout the country, most parts of the country are characterised by prolonged periods of drought between the rainy seasons with rainfall less than the world average [24]. The South African Government in 2001 approved a free basic water policy to deliver at least 6000 L of safe water to each household per month for a household of about eight persons [24]. Since the commencement of the free basic water policy, the household percentage with access to tap or piped water in their dwellings, on-site and off-site (communal taps), has improved from around 55% in 2002 to 70% in 2012. Nonetheless, general access to water by households is only improving by 4.2%, as most households still have to fetch water from dams, rivers, water pools, streams, springs and stagnant water [25].

Water is one of the critical requirements for the proper functioning of biogas technology. An equal amount of water is mixed with the required substrate before being fed into the digester. Findings from the survey indicated that households have access to water within a walking distance of 20–30 mins from the household but are still faced with acute, irregular supply and shortages that have marred most parts of

the province. Water supply can be further improved by the government by ensuring adequate and regular supply of water to the households. Also, where possible, government can consider boreholes, rain water harvesting and water storage tanks to augment water scarcity. The provision of water is considered a critical factor in the perception of biogas technology which can enhance its adoption. Availability of feedstock is another requirement that is necessary in the operation of biogas technology because many digesters are failing due to unavailability of dung. Cow dung is considered the major feedstock in the study area. The findings, as portrayed in **Table 2**, revealed that 93% of the households using the technology in the province own livestock, as against 7% that do not own livestock but source for it either by buying or obtaining from neighbours who own livestock. Furthermore, 79.7% of households without the technology own livestock, while 20.3% do not own livestock. This result indicates that with proper awareness and campaign programme, biogas technology can have a foothold in the province as dung are abound for successful adoption of the technology.

4.5 Dearth of private sector participation

The private sector has key roles to play in the promotion of renewable energy, such as in biogas technology in order to make it market-oriented and commercially sustainable. Many countries have limited policies to attract renewable energy participation by private organisations [26]. For instance, in 2009, Nepal had more than 30 private organisations, which were actively involved in the biogas sector. However, only eight organisations were able to install a little over 500 biogas digesters, due to the unfavourable renewable energy policies [8]. In Limpopo Province, private sector participation in the dissemination of biogas technology is near absence. There is only one established biogas actor (Mpfuneko Biogas Project), a non-governmental organisation (NGO) that supports the development, and dissemination of biogas projects in the province. According to 82% of the sampled households with biogas digesters, the organisation (Mpfuneko Biogas Project) was responsible for the installation of their digester. Although private investment in renewable energy technology is being promoted by organisations such as the Renewable Energy Independent Producers Procurement (REIPPP) and the Department of Energy (DoE), the South African government should strengthen existing policies to support private sector energy investments and institutional mechanisms. The energy crisis being witnesses in the country provide a conducive entry point for private sector participation for an integrated biogas household level programme among other alternative renewable energy. More so, there are favourable conditions for the advancement of biogas technology in the province and the country at large; this includes availability of abundant biodegradable animals and crops waste materials.

	Users	Non-users	Total
Livestock ownership	67 (93)	102 (79.7)	169 (84.5)
Do not own livestock	5 (7.0)	26 (20.3)	31 (15.5)
Total	72 (100)	128 (100)	200 (100)

Bolded faces represent frequency and brackets represent percentage frequency. Source: field survey.

Table 2.
Livestock ownership by households in the study area.

4.6 Lack of technical assistance and availability

In most Africa countries, lack of technical assistance in the form of skilled and unskilled personnel is required in the successful uptake of biogas technology. Technical assistance and availability is often cited as a reason for the impeding adoption of biogas technology. Technical knowledge ranges from the construction, maintenance and operation of the technology [27, 28]. Usually, where biogas digesters have been installed, the problem arises of reactors being of poor quality in the installed units. Poor operations and maintenance ability of users have also led to poor performance of the digester, sometimes leading to the abandonment of the technology. In some cases, due to technical availability, many demonstration plants have failed, which served to deter instead of enhancing the adoption of the technology [27, 28]. Technical availability is an integral determinant in the adoption of biogas technology at household level in the province. Available technical availability and assistance are deemed as a good support for the dissemination, adoption and utilisation of the technology. Due to inability of proper management, resulting from absence of technical expertise, several biogas projects have failed. The study reported that unreliable and unavailable technical services were common problem reported by households with installed digesters. In addition, households with interest about the technology shared the same sentiment about their perception to the technology. The question of technical support was directed to households with installed digesters and the findings show that 96% of the households complained about technical assistance of any sort. Technical issues faced by some households included blocked and leaking pipes, cracked and leaking digesters chambers, which has limit the use of the technology and sometimes leading to total abandonment. To promote the implementation and proper use of biogas technology, it is imperative to initiate long-term, biogas technology capacity-building programmes as well as training and execution of scientific work in the field through applicable research. There is the need for adequate technical expertise in the construction and maintenance of biogas digesters. Biogas technology and its implementation techniques can be introduced in the curriculum of most engineering and technical courses offered in universities, vocational and technical colleges that can train people on how to build and maintain biogas digesters.

4.7 Cost associated with installing biogas digester

One frequently cited factor limiting the development of biogas technology is financial constraints. In Ghana, for example, according to Arthur et al. [17], the findings indicated that, although the technology can solve some of the environmental and energy challenges faced in the urban and rural parts of the country, the technology requires a high initial cost of investment. In Ethiopia, one of the obstacles hindering the use of the technology by the rural cattle farmers is their inability to cover the full cost associated with installing the technology [21]. According to Bensah and Brew-Hammond [29], the principal hindrance to biogas technology expansion in Ghana is the cost of building the digesters, which most farmers have complained about. In South Africa, the average cost of mounting a smallholding biogas digester of 6 m³ ranges from R15,000 to R40,000 [30], whereas a 10 m³ digester costs not less than R80,000 [20]. Therefore, subsidies can enhance the relative advantages and speed up the adoption of biogas technology by those entities who would not have ordinarily adopted the technology [31]. Furthermore, some technologies have socially desired features; thus, adopting such technology is not only beneficial to the owner but to the society. In many of the Organisation

for Economic Cooperation and Development (OECD) countries, companies and individual households can seek government subsidies if they adopt technology that is socially desirable. Even if the investment cost surpasses private benefits but is lower than social benefits, government provides subsidies to enhance the adoption of technologies that provides social benefits [32]. Furthermore, the size of the subsidies significantly influences the rates of adoption. In China, for instance, there was a time when interest in adopting biogas technology was fading away just after the government reduced subsidies to one-third of the investment cost from two-thirds [33]. In Nepal, it was revealed that without subsidies, most of the Nepalese farmers would not have been able to adopt the technology, due to their financial constraints [34]. Although providing subsidies may also not positively increase the intended adoption rate of the technology. Individuals who adopt the technology for the sake of obtaining subsidies may be less enthusiastic to keep using the technology [35].

Additionally, households consider a variety of issues in their decisions to either to adopt or reject using modern energy technologies. Among other considerations, cost is of critical importance affecting the final decision by the consumer. Most consumers would prefer a modern technology with low initial costs compared to one that minimised cost of operations but ran over an extended period. Thus, creating a balance between initial costs alongside operation cost is important. In countries with low income, where individuals lack access to credit/ and or cash, widespread preference is often associated with low initial cost [36]. In supporting the argument, Bajgain [34] stated that in Ethiopia, high initial cost of investment remains a major obstacle in the prevalent dissemination of biogas technology. In the absence of subsidies, loans and credits, the uptake of the technology at household level can only be driven by income earned by the household. Consequently, the higher the income earned, the more likely it is for the household to adopt the technology compared to households earning lesser income. Thus, income is expected to influence the perception and thus adoption of the technology. This is because households consider a range of issues in their choice to either adopt or reject modern energy carriers. In the study area, the monthly income earned is low compared to other provinces in the country, due to the high unemployment rate that has characterised much part of the province. From the field survey results as shown in **Table 3**, only 15 households from the technology users' category, representing 20.8%, earn above R3501, with 18 households, representing 14% earning above the same amount from the non-users. Most of the users and non-users of the technology are in the monthly income bracket of

Income (ZAR ^a)	Users	Non-users	Total
R0–500	08 (11.1)	16 (12.5)	24 (12.0)
R501–1000	12 (16.7)	31 (24.2)	43 (21.5)
R1001–1500	17 (23.6)	33 (25.5)	50 (25.0)
R1501–3500	20 (27.8)	30 (23.5)	50 (25.0)
R3501+	15 (20.8)	18 (14.0)	33 (16.5)
Total	72 (100)	128 (100)	200 (100)

^a1 USD = ZAR 14.90.
Bolded figures represent frequency and brackets represent percentage frequency. Source: field survey.

Table 3.
Monthly income bracket of surveyed households of biogas users and non-users in the study area.

	Value	df	Asymp. sig. (two-sided)
Pearson's chi-square	43.251 ^a	3	0.000
Likelihood ratio	41.598	3	0.000
Linear-by-linear association	19.917	1	0.000
No. of valid cases	200		

^a0 cells (0.0%) have expected count less than 5. The minimum expected count is 8.91.

Table 4.
Pearson chi-square test results for income and costs of installing biogas digester.

R501 to R3500. As noted by [20, 30], the households cannot afford the average cost of installing a smallholding biogas digester.

As shown in **Table 4** using the Pearson’s chi-square test, income earned by households was cross tabulated against the cost of building a digester, to determine the significant relationship between both variables. The result at $p < 0.05$ indicated that there is a statistical significant relationship between the income earned and the cost of installing a biogas digester. This implies that income earned by households in the province affects the adoption of the technology. As noted, the low income earned by the households sampled is a factor of socio-economic challenge being faced in the province, hence households finding it difficult to save and invest in a technology such as biogas. This can however be overcome by provision of loans, credits or subsidies to interested households willing to adopt the technology in order to relieve them of other households’ burden as practised in other countries [36].

5. Conclusion

Drawing from the field survey, this chapter provides first-hand empirical evidence on the awareness and perceptions of biogas technology in the province by understanding the challenges in disseminating the technology. Despite the potential of biogas technology in forming part of the energy mix in households and providing environmental benefits, the level of awareness and perception of the technology remain low in the province. In any given technology, the awareness and perceptions of the users have been found to play an important role in the adoption and utilisation of the technology. Households’ awareness and perceptions of biogas technology were investigated in order to get a deeper insight into the barriers to its adoption and utilisation in the province despite the prevailing conditions such as the abundance of dung to support the uptake of the technology. From the sampled households, the awareness was measured based on the financial implication, functionality and dissemination of the technology. Using the Pearson chi-square, the cost of biogas digester and income earned established a statistical significance relationship at $p < 0.05$. The perceptions of the technology was measured based on households insights regarding the role of biogas in fuel crisis, soil fertility, livestock management, burden of fuelwood collection, livestock ownership, water and feedstock availability as well as technical availability and assistance. In order to understand the in-depth perceptions of the households, the variables were further tested using a Spearman rank correlation coefficient at $p < 0.05$, with a calculated value of 0.68, indicating that there is a positive and strong correlation in the perception of biogas technology among the users and non-users households in the province. The study thus argued that the aforementioned variables are key in the dissemination and adoption of the biogas technology in Limpopo Province.

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