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# Impact of Biogas on Sustainable Livelihood in Rural Areas A Case Study of Swat, Pakistan

**Dilawar Farhan Shams[1], Afghan[2], Muhammad Qasim[2], Salma Khalid[2], Kamran Hussain Shah[3]**

[1] Assistant Professor, Department of Environmental Sciences, Abdul Wali Khan University Mardan, Pakistan
[2]Department of Environmental Sciences, Abdul Wali Khan University Mardan, Pakistan [3] World Wide Fund for Nature, Pakistan

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**ABSTRACT**

This study assessed the efficacy of biogas plants installed in rural area of District Swat Pakistan in terms of its impact on socio-economic and environmental factors. A questionnaire survey was conducted using random sampling technique among the beneficiary populace covering the utilization of biogas, operational issues, economic benefits, changes in the consumption of fuel-wood and other energy sources, health, pollution and waste emissions and locals' approval of the biogas technology. The findings revealed that the introduction of biogas in the area appreciably affected the livelihood of the people as cheap and convenient energy source principally used for cooking and heating while also providing organic manure for soil fertility. The survey deduced a marked decrease in indoor air pollution, respiratory diseases, $CO_2$ emission, deforestation and waste generation due to the decrease in burning of fuel-wood, dung and crop residues. On the economic side, the beneficiaries were able to save, in some cases up to PKR 20,000 per month by spending less on utility bills and purchase of other fuel sources and fertilizers. On the contrary, production of odour indicated by a small fraction of the users and financial constraints in installation of biogas plants was also found however, with the approval of nearly 90% respondents in favour of biogas and its positive economic and environmental impacts, biogas offer prospective alternative solution to cater for the energy demands of rural population in a sustainable manner.

**KEYWORDS:** Biogas; economic; environmental; questionnaire survey; sustainable; Swat.

## 1. INTRODUCTION

Energy is a fundamental requirement in today's world to sustain the quality of life, ensure better living, economic production and growth, and employment. Any shortage in the supply of energy to the national economy could disrupt the economic process and livelihood of people. This is the case with Pakistan, which is facing serious energy shortfall for the past few decades due to poor planning and mismanagement and now increasingly relying on non-renewable fossil fuels energy spending almost 7.0 billion US dollars annually [1].

Shortage of energy for electricity generation and fuel is a major hurdle in the path towards development, economic growth and prosperity in the country. As the demand for these two is increasing, a significant rise in prices is also observed, which further makes the situation precarious for the predominantly poor and middle-class populace. In Pakistan, the fuel used for domestic consumption, particularly in urban areas is natural gas. In rural areas where natural gas is not available, liquefied petroleum gas (LPG) is used after fuel-wood, dung and crop residues. However, it is becoming unaffordable for the people as its price has jumped in recent years. Due to the overburden of urban population on limited natural gas, it is becoming impossible to supply it to rural areas. Likewise, fuel-wood supply is also decreasing due to over-cutting and deforestation. In such a case, renewable and sustainable energy resources are best substitute to the conventional fuels and energy sources. One of the potential alternative energy sources in rural areas is biogas due to the abundance of biodegradable livestock and agriculture wastes. Biogas is a combustible mixture of gases comprising mostly of methane ($CH_4$) and carbon dioxide ($CO_2$) and is formed by anaerobic bacterial decomposition of organic matter. The actual composition of biogas depends on the characteristics of material decomposed, but generally it is composed of $CH_4$ (55-70%); $CO_2$ (27-44%); hydrogen sulphide ($H_2S$), hydrogen and ammonia (1-2% each), and carbon monoxide, nitrogen and oxygen in trace amounts[2].Biogas, besides replacing conventional fuels in rural areas such as fuel-wood is also a waste to energy concept which leads to better waste management strategies for future.

Pakistan, being an agricultural country, has a great potential for the installation and production of biogas due to a large population of rural livestock, availability of animal dung and agriculture waste. On one hand, it is a cheap energy source thus cost-effective while at the same time also environment friendly. Domestic biogas plants were started in Pakistan in 1959 and at present, a large number of such working units have been installed especially in backward, deprived and disaster affected regions. One of such regions in District Swat in the north-west regions of Pakistan, which is energy deprived and was drastically affected by the flash floods in 2010. To cater for the energy needs of rural population in District Swat and their rehabilitation, the World Wide Fund for

**Corresponding Author:** Dilawar Farhan Shams, Department of Environmental Sciences, Abdul Wali Khan University Mardan, Pakistan. Email address: drfarhan@awkum.edu.pk

Nature (WWF) with funding from the United Nations Development Program (UNDP) installed around 100 biogas plants in flood-affected rural dwellings of District Swat having plenteous availability of organic matter for biogas production. The cost of installation of a biogas plant at the household level was approx. US$700 which was either totally or partially born by the project while labour was provided by the beneficiary. This study was aimed at evaluating the efficiency of biogas plants in Swat, its socio-economic, health and environmental impacts on the community and acceptability by the consumers using a questionnaire survey of the project beneficiaries.

## 2. MATERIALS AND METHODS

### 2.1. Introduction to the project area (Swat, Pakistan)

District Swat is located in the Hindukush mountain range in the Khyber Pakhtunkhwa province of Pakistan with a total area of 5337 square kilometres. It is situated at 34$^{o}$-40 to 35$^{o}$-55 North Latitude and 72$^{o}$-08 to 74$^{o}$-06 East Longitude. Swat is one of the districts of Malakand Division and it is one of the greener parts of Pakistan that is blessed with natural resources like forests, fresh water and fertile soils that having a remarkable support to the biodiversity. Once the entire area was covered with thick forests, which has declined over the years due to overuse of forest resources. Administratively, Swat has been divided into two parts, the Swat Kohistan and Swat proper. Again there is a sub-division of Swat proper into Bar (upper) and Kuz (lower).The entire population of the district was 12.5 million while average annual growth was 3.37% in 1998. People are mainly Pushtuns belonging to "Yousufzai" tribe with Pashto as the local language. Being located in a temperate zone, Swat has its climate controlled by a number of factors like latitude, altitude, summer monsoons and the cyclonic currents in winter that comes from the Mediterranean Sea. Winters are severe with a minimum temperature of -2$^{o}$C, while comparatively, summers are moderate with a maximum temperature of 34$^{o}$C. Average annual precipitation is about 1000-1200mm.

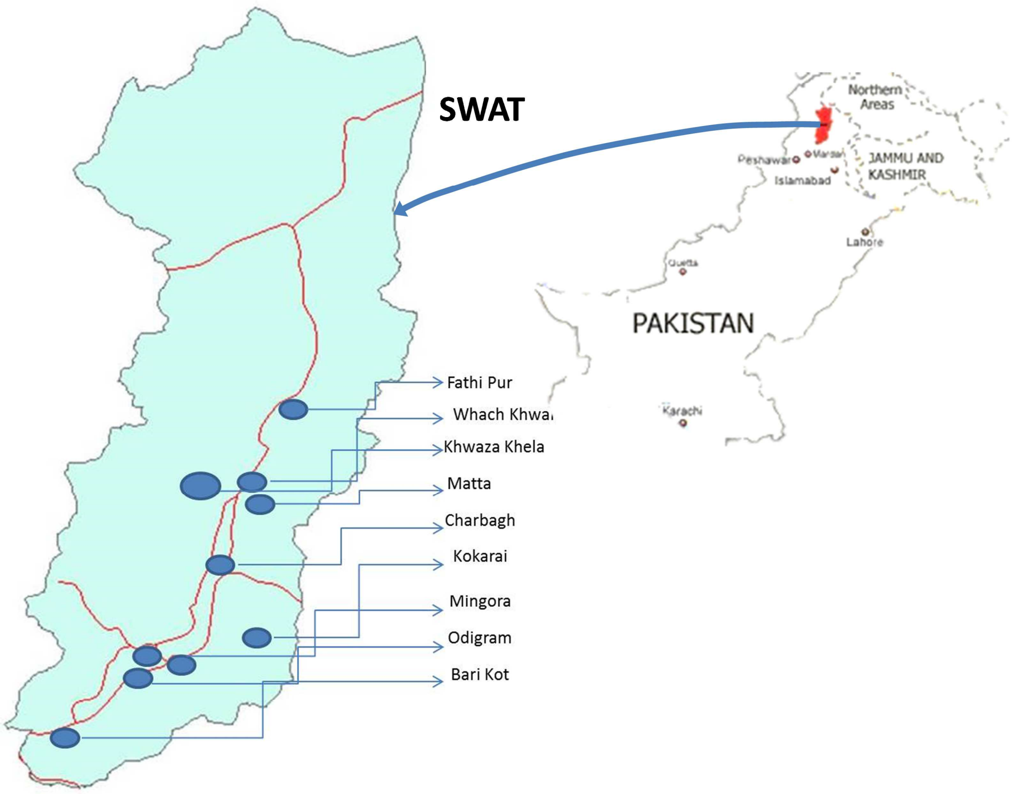


**Fig.1.**Location of the project area in Pakistan

### 2.2. Biogas facility design

The biogas plants studied in the current study are fixed dome type plants (Fig.2). Such plants comprise a digester in the form of a shallow well with a dome shaped roof over it. The digester is connected to the inlet and outlet through sloping channels. The gas pipe is fitted on the crown of the dome shaped digester[3]. These require less maintenance with low footprint while being underground however maintaining the gas pressure in such systems is challenging and require diligence[1]. The biogas plants were installed by WWF as part of the UNDP restoration aid intervention to the local affected population in District Swat. A total of 100 plants were installed in Matta, Swat, Kabal, Khwaza Khela, Charbagh, Barikot, Babozai regions (Tehsils) throughout District Swat, Pakistan.

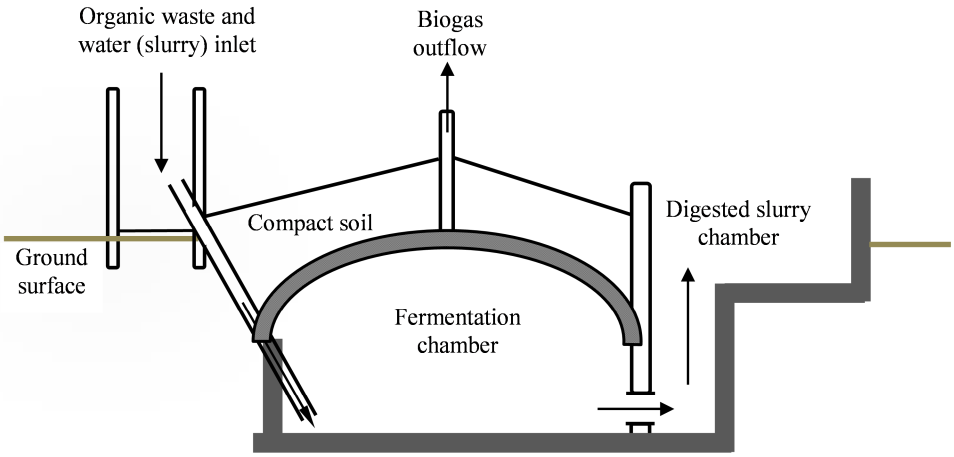


**Fig.2.**Configuration of the installed dome based biogas plants

### 2.3. Data collection

Questionnaire survey was conducted to obtain primary data. Each questionnaire comprised of 15 questions (both structured and unstructured) pertaining to different aspect of biogas facilities. The questionnaires were filled from 40 randomly selected biogas plant owners covering all the villages in the project area through interview schedule. Formal and informal meetings were also held with the local people and relevant experts (field engineer, field supervisor and project in charge) to get additional information about different aspects of the biogas plants. In addition, field visits were also made to the sites where biogas plants were installed to physically observe the status and take GPS readings of the sites.

## 3. RESULTS AND DISCUSSION

### 0.1. Uses of biogas

Biogas in the study area was principally used for cooking as indicated by its consumption in 83% of the households (Fig.3). In 13% of the cases, biogas has also been used for miscellaneous purposes such as lighting etc. On the other hand, generation of electricity from biogas plants was negligible with only 5% employing it for electricity production primarily due to the lack of awareness. With major amount of gas produced directed towards cooking and heating, biogas has reduced burden on the non-renewable natural gas as well as fuel wood collected from forests in the mountainous region.

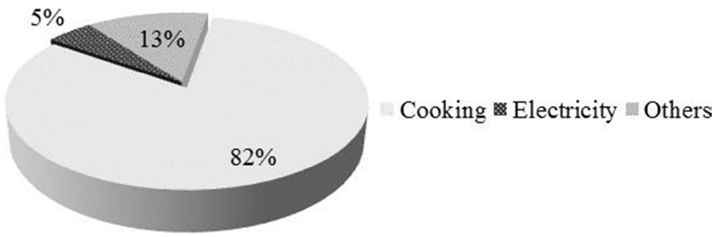


**Fig.3:** Purpose of biogas plant

### 0.2. Slurry management

The digested bovine dung was released as by-product on daily basis in the form of slurry. About 47 % of the slurry produced was used as fertilizer or soil conditioner, 15 % was sold in the market, 35 % was disposed of at dumping sites while 3 % was stored for future use as shown the Fig. 4. The fertilizer produced from biogas digesters is reported to be of good quality rich in nitrogen, phosphorus and potassium contents [4] and its use as soil manure improve micro-flora and building the soil structure and texture[5].This causes a dual benefit as it not only treat animal wastes but also save income spent on purchase of synthetic fertilizer and reduce environmental risks related to animal wastes thus promoting sustainable development[6]. Dumping, compared to selling in the market or for future use was prevalent mainly as very few people were aware of the economic value of slurry or compost as a fertilizer that is preferred over synthetic fertilizers in terms of cost-effectiveness and nutrient recycling.

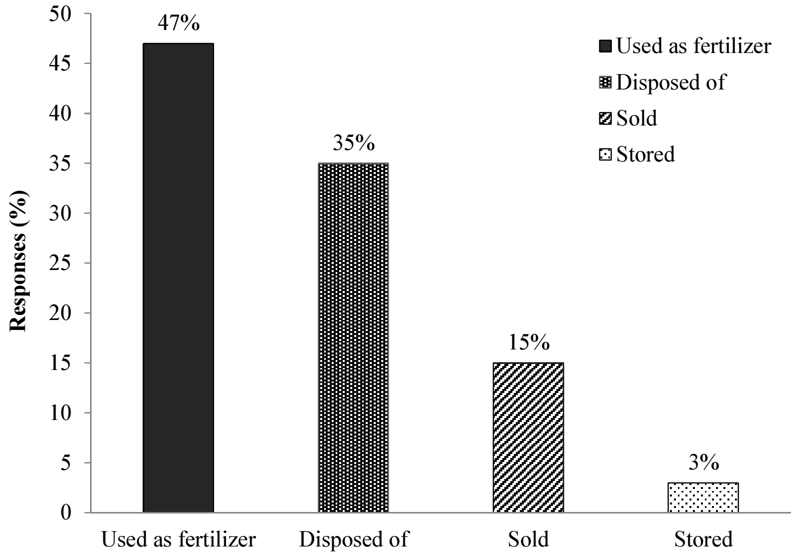


**Fig.4:** Usage of the released slurry/compost

### 0.3. Effect on fuel-wood and gas consumption

Decrease in fuel-wood consumption was considerable. The major energy source for cooking and heating in the study area was fuel-wood sourced from the forests that has over the years, significantly declined due to excessive deforestation in the area[7]. Biogas had successfully contributed to decreasing the rate of deforestation in Swat. This is demonstrated from the opinion of 87% of the respondents pointing towards a decrease in fuel-wood consumption and therefore tree cutting. This portrayed biogas plants as an eminent green technology adding to sustainability in terms of environmental protection and resource conservation. A reduction in fuel-wood consumption of up to 2 tons has been reported with the use of biogas that contributed significantly to reduce deforestation rates and overall improvement in the environment[4]. The reduction in fuel-wood consumption has also reduced the drudgery of women and children in collection of fuel-wood, which enables them to carry out other productive activities[8].

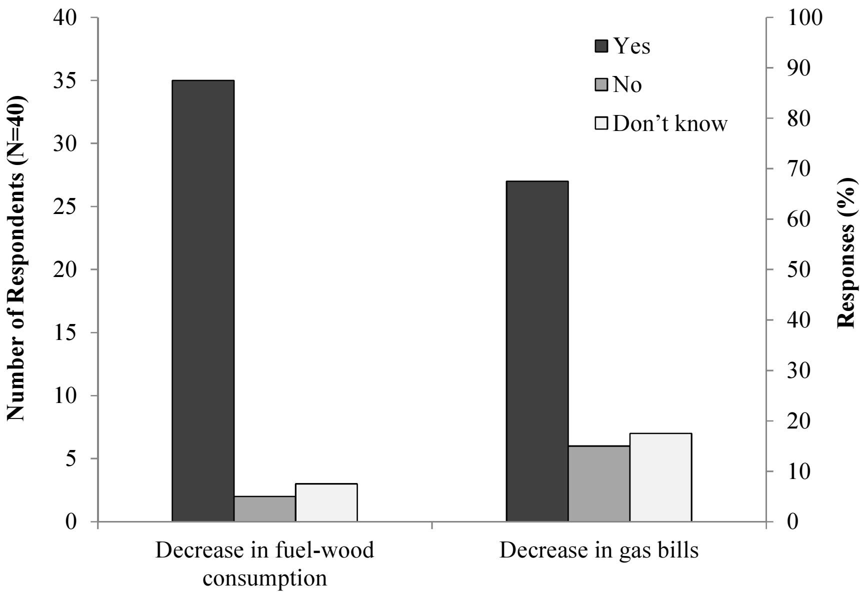


**Fig.5:**Decrease in fuel-wood cutting/deforestation

### 0.4. Economic benefits

The shift over to biogas resulted in significant cost savings and about 67% of the households survey observed considerable decrease in amount spent on purchasing liquid pentane gas (LPG), which is used as the common source energy beside fuel-wood. From an environmental standpoint, the substitution of LPG with biogas is beneficial for conservation of non-renewable fossil fuels while at the same time reducing the burden on the economy through savings in the national exchequer allocated for the import of LPG. From the community point of view, cost savings in general were achieved due to lesser use of fuel-wood, procured gas and in some cases from electricity generation. It is estimated that the expenses on conventional bio fuels like LPG, dung cakes, fuel wood and chemical fertilizer account for about PKR 3550 while health maintenance costs account for about PKR 1000 [1]. According to the survey, 40% of the households were saving up to PKR 5000 per month, while 35%, 5%, and 5% saved up to PKR 10,000, PKR 15,000 and PKR 20,000 respectively which favourably supported the economic benefits of biogas.

### 0.5. Effect on indoor air pollution disease prevalence

Burning of solid fuels such as biomass fuels (fuel-wood, dung, crop waste)and coal at homes and the resulting smoke is associated with the prevalence of a variety of indoor air pollution (IAP) diseases such as lower respiratory disease, chronic obstructive pulmonary disease, eye disease, cancers, and others mostly in poor countries[9]. According to (WHO, 2002), in Pakistan, annually 300-400 deaths per million population are caused by indoor air pollution. In the study area, in general, reduction in the incidence of IAP diseases have been indicated by the respondents with 70% suggesting significant decrease in the intensity of respiratory and eye diseases citing the reduction in smoke as the primary cause. Meanwhile, 15% were of the view that IAP diseases such as eye irritation and coughing due to smoke have vanished whereas remaining 15% were of the view that smoke-free indoor environment has enhanced the health and well-being of women. Reduction in indoor air pollution is also associated with decline in in the concentrations of formaldehydes, carbon monoxide and suspended particles[4].In addition, the burning of wood and dung cakes produced unpleasant odours, which was lesser with the biogas burning as evident from the 83% favourable response. The detectable bad smell indicated from the 17% responses was sourced from leakage from anaerobic decomposition in the biogas plant. Similarly, conventional fuels such as fuel-wood and dung created bad taste in food that was absent with the biogas.

### 0.6. Reduction in greenhouse gas emissions

Biogas in general results in no net production of greenhouse emissions. The material digested in biogas is mainly of plant origin, therefore it only induce the cycle completion from atmosphere to plants and animals and then back to atmosphere. However, digestion significantly reduces $CO_2$ emissions compared to burning of the same materials. Myles [5]reported that burning of 1 Kg dried dung produced an average of 2.5 Kg $CO_2$ emissions whereas biogas plant with a capacity of 2 $m^3$ can digest about 50 Kg (equal to 10 Kg dry dung) while emitting 40% less $CO_2$ than burning dry dung (dung cake). According to these estimates, biogas plant with a capacity of 10 $m^3$ (average plant capacity in this study) will emit 75 Kg $CO_2$/Kg dry dung compared to 125 Kg/Kg with dung cake burning. This means a significant reduction in $CO_2$emissions from the digestion of only dung. Carbon dioxide and methane production would also have been reduced with decrease in burning of fuel-wood that produce $CO_2$ and $CH_4$ at a fraction of 1.83 Kg/Kg and 3.9 g/Kg respectively.

### 0.7. Change in production capacity

Decrease in the productive capacity of the biogas plant with time is a common problem. Since the surveyed area plants have been recently installed, therefore no significant decrease (63%) was observed. Only 12% of the respondents witnessed decrease while 25% have no idea about the decrease in productive capability. The decrease was mainly attributable to effect of temperature on the production of biogas because the degradation rate of organic matter is more rapid at elevated temperatures[10]. Temperature decrease can be a problem since the production of methane gas from hydrogen is fastest at 65 ºC. Biogas digester recommended temperature is below 60°C to facilitate thermophillic digestion to avoid effects of fluctuating temperature on microbial activity. The winter season of the study area is comparatively longer than summer and temperature of the area throughout the year did not exceed 38°C. About 35 % of the respondents observed decrease in production with lower temperature during rain and/or arriving winter, while 65 % of the respondents did not associate any effect of temperature on biogas plant efficiency.

### 0.8. User's appraisal of biogas

In view of cost-savings from biogas, lowered health problems, social uplift and beginning of reestablishment of the forest cover, local populace in general were approving of the introduction of biogas technology in the area. With regards to the performance of biogas facilities, 90% of the respondents were satisfied with the plants' operation. The remaining 10% disagreed mainly due to operational issues. Safety problems associated with operating biogas plant were negligible since all of the respondents didn't report any associated safety hazard from the biogas plants.

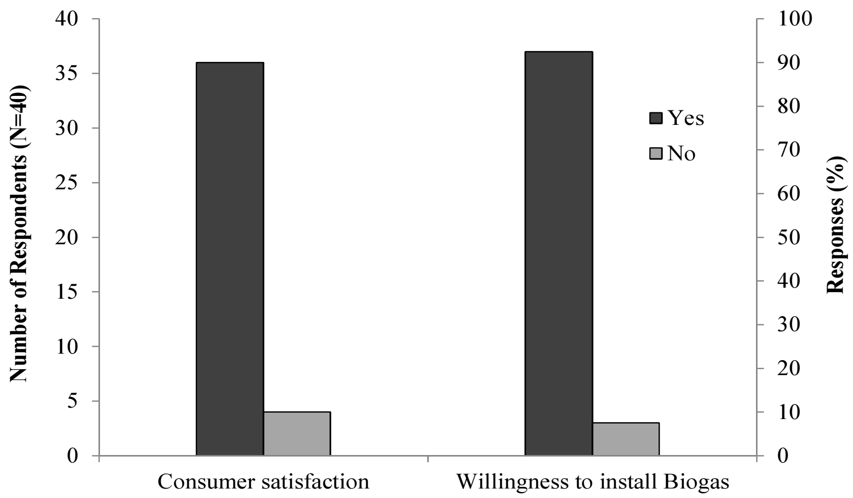


**Fig.6:** Consumer satisfaction and people willing to install biogas plants

On the other hand, 92% of the people were eager to install biogas plant due to the associated benefits while 8% of the respondents were not ready to have biogas facility primarily. The reasons cited were cost unaffordability, lack of expertise, lack of livestock, lack of communication with concerned people, lack of interest in investment, lack of space/animals and unwillingness to pay total cost. According to the results 52% respondents were facing economic problems in installing biogas plants, 15% lacked livestock, 3% complained about the lack of expertise while the rest cited other issues as mentioned above.

## CONCLUSIONS

Biogas production and consumption induced significant socio-economic and environmental impacts on the livelihood of the rural dwellers. The produced biogas was mainly used for cooking and heating, with lesser electricity while by-product was mainly used as soil conditioner. Decrease in indoor air pollution, respiratory and other smoke related diseases, and $CO_2$ emissions have significantly reduced with the switch over to biogas. Meanwhile, deforestation also decreased as well as the time and effort for collection of fuel-wood from forests. Savings were also achieved however, reported presence of foul smells by some respondents possibly due to leakage of $H_2S$ and methane from the digester and financial constraints in bearing the cost of biogas plants are some of the factors hindering the people from installing biogas facilities. Nevertheless, large majority of surveyed people favoured biogas to cost-effectively cater for their energy demands.

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