Modeling biogas technology adoption in Pakistan: A way forward for sustainable research of energy

Shahid Ali
North China Electric Power University
Qingyou Yan
North China Electric Power University
Rajvikram Madurai Elavarasan
Texas A&M University
Muhammad Irfan (irfansahar@bit.edu.cn)
Beijing Institute of Technology https://orcid.org/0000-0003-1446-583X
Kashif Raza Abbasi
Shanghai University
Cem Işik
Anadolu University

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Modeling biogas technology adoption in Pakistan: A way forward for sustainable research of energy

Shahid Ali [a], Qingyou Yan [a,b], Rajvikram Madurai Elavarasan [c], Muhammad Irfan [d,e,*], Kashif Raza Abbasi [f], Cem Işik [g]

[a] School of Economics and Management, North China Electric Power University, Beijing, 102206, China

[b] Beijing Key Laboratory of New Energy and Low-Carbon Development, North China Electric Power University, Beijing, 102206, China

[c] Clean and Resilient Energy Systems Laboratory, Texas A&M University, Galveston, TX, 77553, USA

[d] School of Management and Economics, Beijing Institute of Technology, Beijing 100081, China

[e] Centre for Energy and Environmental Policy Research, Beijing Institute of Technology, Beijing, 100081, China

[f] School of Economics, Shanghai University, Shanghai 200444, China

[g] Faculty of Tourism, Anadolu University, Eskişehir, Turkey

Abstract

The extensive need for energy has become a global issue due to the enormous population growth and demand for electricity-based products. Energy crises are rapidly increasing, which have destructive impacts on the industry in Pakistan. Biogas technology adoption is a challenge in a developing country like Pakistan. The government sector has taken initial steps to eliminate the energy crisis and promoted biogas plants. The primary objective of this study is to explore the satisfied and unsatisfied ratio of farmers who have adopted biogas plants in the country. The sample size was identified through the snowball sampling method. A total of 51 biogas adopters participated in this study. The structured questionnaires were used to collect data through online interviews. The results indicate that 34% of biogas plant respondents were satisfied with their plant feedback. The partially satisfied respondents were 24%, whereas 42% showed unsatisfaction. More than half (58%) of the respondents expressed that biogas plants are in good working conditions; however, 42% of biogas users were unrestrained for several causes. The findings of this study indicate that major maintenance and day-to-day operations of biogas plants are expensive due to lack of skilled operators, untrained or partially trained owners, and unavailability of technicians. The results suggest that the government needs to plan a clear policy, technical support with skilled technicians to biogas plant owners, all through an integrated and coherent way.

Keywords: Renewable energy; biogas resources; trade using biogas technology; potential; barriers; Pakistan

* Crresponding author
Email addresses: 120194300011@ncepu.edu.cn (S. Ali), yanqingyou@ncepu.edu.cn (Q.Yan), rajvikram787@gmail.com (R.M.Elavarasan), irfansahar@bit.edu.cn (M. Irfan), kashifabbassi@shu.edu.cn (K.R. Abbasi), cemisik@anadolu.edu.tr (C. Isik)

1. Introduction

Current lifestyle and economic growth are impossible without a continued supply of energy. Consistent availability of energy is highly required for modern life. The economic growth and success of the nation are greatly dependent on the proper use of energy resources (Ikram et al., 2020). Energy plays a fundamental role in improving the standard of living and economic development of any country or nation. Energy worked as a vital building block for developing country's economic and social development (Carmona et al., 2021). The energy demand and supply gap create issues in almost all country sectors, including sustainable development, prosperity, development of other sectors, and economic growth. These issues are considered harmful for human health, water resources, agricultural productivity, and environmental activities(Arshad et al., 2018). But at present, energy generation is a challenging job with the use of modern technology. The increasing population and current economic development are the reasons for the country's extreme demand for energy. Most portion of the power is generated from fossil fuels in Pakistan. Conversely, these sources of energy generation have opposing environmental impacts and are also high priced. The government of Pakistan has decided to eliminate the major energy crisis by using alternative, clean, and cost-effective energy sources. Modern RE methods address environmental problems and provide solutions for all energy issues (Yasmin and Grundmann, 2019) justifiably. Renewable energy (RE) has contributed 2.4% to the total energy mix of the country. However, the government of Pakistan has decided to enhance the share of RE by 5% until 2030, but biomass energy is playing a vital role in achieving this target(Irfan et al., 2020). Biogas adoption negatively impacts the collection of time and fuel-wood expenditures, but it has a positive and significant impact on crop revenues and income (Yasmin & Grundmann, 2019).

The current shortfall of energy in the country can be overcome by the effective and efficient use of biogas as an alternative energy source. Biogas provides practically 14 percent of primary energy because it is the fourth important energy source worldwide (Amir et al., 2019). Pakistan has prodigious potential to produce energy from biogas because it has the sixth-largest livestock-based economy globally (I. Jan & Akram, 2018). Conversely, biogas adoption is financially feasible and also environmental-friendly (T. Abbas et al., 2017). Biogas energy contemplates as a trustworthy and favourable alternative energy source from several available RE technologies. Agriculture is the primary profession in Pakistan and contributes 18.5% of gross domestic product (GDP) by providing 38.5% of employment opportunities to its whole population. Biomass has massive potential to produce energy in Pakistan and reduce the gap between demand and supply (Uddin et al., 2016). The biogas plant is economical due to installation cost and also beneficial to minimize eye contaminations and respiratory. Pakistan Council of RE Technologies has installed 4109 biogas plants throughout the country. It saves an average of Rs, 37.925 million per month in different terms such as liquefied petroleum gas, wood, kerosene oil, and biofertilizer (Javed et al., 2016). Energy has a critical importance for sustainable development in the country. Developing countries are facing a severe economic burden to import gas and oil. Pakistan is consuming a sizeable national treasury to import gas and oil to reduce the temporary energy shortage. Pakistan has saved \$8- \$9 billion from energy import bills in 2019-2020 (GoP, 2020). It is an admitted fact that economic development and energy are incredibly interdependent (Oyeleke & Akinlo, 2019).

Many countries worldwide, including low-middle income, have invested in different RE technologies such as solar thermal, biomass, and hydro to generate reliable, indigenous, and affordable energy (Marion et al., 2017). Biogas generation through anaerobic digestion from organic waste has been acknowledged as a sustainable energy source (Ur et al., 2019). Many research studies have discussed in the literature that biogas provides energy to specific rural areas and fills the different types of gap, such as reducing poverty, creating local jobs, and improving health for economic growth (Bates et al., 2019; Mikhail et al., 2020). Biogas production provides several environmental benefits such as power generation & sustainable energy, waste treatment, and bio-slurry as organic fertilizer to improve stamina in crops. Many reasons for deforestation are explored in rural areas of low-middle-income countries, such as energy shortage, sluggish growth, and lack of biogas production. So, women of rural areas tolerate the burden of burning and woodcutting for cooking and heating (Rosenthal et al., 2018). The agriculture sector is a supplement as nourishment for the economy of Pakistan. Agriculture is the primary source of revenue for a big portion of the population in the country. Consequently, the well-promoted biogas slurry use in agriculture can improve the soil health & production of crops and curtail the cost of fertilizers ultimately (Afridi & Qammar, 2020).

Biogas production and bio-slurry collection were effectively supported through biogas users for soil fertility (Ashraf et al., 2019). Livestock products encompassed with milk such as milk products or other products consumed at the domestic level. Milk is the main component of livestock products that are domestically consumed by the milk products. The cost of livestock products was high at 64 percent, consumed domestically, but other sold products are 34 percent due to market absence. Household women were participated in 73 present significant shares in livestock income and showed their best contribution in livestock nature (Naz & Khan, 2018). The output of these items, such as mutton, eggs, bones, and fat, have a significant and positive relationship with agriculture GDP in Pakistan. In contrast, the output of some specific items such as hair, wool, skins, beef, poultry, and hides have an insignificant or negative relationship with agriculture GDP in Pakistan (Rehman et al., 2017). The sub-sectors of agriculture were contributed significantly and positively to the agricultural GDP of Pakistan. In agriculture, the government paid less attention to the forestry sub-sector and was considered very poor compared to other sub-sectors (Chandio et al., 2017). Livestock contributes significantly to the development of livelihoods and the economy because it is an essential part of agriculture in Pakistan. The country has produced 650 million kg/day of animal dung, with an estimated livestock population is 207.4 million. It can also provide biogas 16.25 million m3/day to the consumers if 50% of animal dung is collected and processed with the country. This estimated amount of biogas can assist in energy poverty eradication and support rural areas in Pakistan. Agriculture contributes 19.3%, but the livestock sector contributes 11.7% to Pakistan's Gross Domestic Product (GDP). More than 8 million families are linked with farmhouse businesses directly engaged in producing livestock products and earned their total output around 35-40% from this sector (GoP, 2020). However, some livestock items are associated with the significant growth of the economy, such as fat, bones, milk, eggs, and mutton (Rehman et al., 2017).

Livestock is a sub-sector of agriculture in Pakistan, and most of the population is associated with this sector. The prosperity and source of income can be increased with the development of the livestock sector and innovation to produce its products (Alvi et al., 2015). Livestock is vital in generating biogas energy, a cost-effective alternative energy source, because Pakistan meets 28.12% of energy needs through imported gas and oil (Duan & Chen, 2017). Biogas technology has a bright future in Pakistan and can also support eliminating the energy deficit from the country (Ashraf et al., 2019). Pakistan has an animal-based huge population and production of biogas potential by using animal dung (Y. Wang et al., 2020). Pakistan is producing 129 ton/day animal dung collections that can make a possible quantity of biogas. The average amount of biogas 12-804 m3/ day can be produced through animal dung in the village area of Pakistan (Shah & Sahito, 2017). The government of Pakistan has started a biogas project by using biogas technology for social benefit in 1974. The 4137 biogas plants were installed in rural arrears till 1987. The per-day biogas plant capacities were 3,000 ft3 to 5,000 for cooking and lighting (Kamran, 2018). In 2008-2009, Pakistan started its domestic biogas project program to provide biogas plants and replaced conventional fuels such as leftover crops, liquefied petroleum gas, wood, and animal dung cake (M. I. Jan, 2017). The primary purpose was to construct 12,000 biogas plants by this specific program. Unfortunately, only the estimated 3,000 biogas plants were connected, but desired goals were not accomplished. The program was offered subsidy by way of incentives to up great and encouraged population of rural areas for social and technological adaptation. Still, biogas technology acceptance has not received the required, favorable rate (Mushtaq et al., 2016).

The primary reason behind the installation and construction of biogas plants was the inspiration of energy, saving of time, and subsidy. The 42.5% key motivational and subsidy influencing factors included subsidy, tax, and finance for the cleaner fuel adoption (Puzzolo et al., 2016). social reputation and time-saving are also considered motivational factors and accounting for 33.5% for each, respectively. The technology progress in low-middle income countries with social acceptance is highly linked. The fact about social niche starts with the behaviour of individuals, and existing social practices are linked with it. For the health advantage, the lowest case in percentage was 13.7% that is a trait of an awareness level of adopters (Pilloni et al., 2020). Table 1. Indicates the reasons of inspiration to adopt biogas plant from plant users.

Table 1. Reasons of inspiration concerned with biogas plant

Reason	Cases (%)	Response (%)	Frequency
Motivation by construction body	32.5	11.5	18
Motivation by existing plants	42.3	14.8	22
Subsidy	42.5	14.8	22
Unavailability of alternative fuels (same time)	20.7	7.6	11
Environmental advantages	18.7	6.1	8
Health advantages	14.8	5.7	10
Time saving	30.5	10.9	16
Energy-saving	30.6	10.8	15.5
Social reputation	32.5	11.15	17

Oppositely, Biogas plants are very successful, running with a higher number in South Asian countries such as China, Bangladesh, India, and Nepal (Nevzorova & Kutcherov, 2019). Hence, some barriers and important factors closely discourage the acceptance rate of biogas technology in the country. While biogas technology is still not socially acceptable in Pakistan, even this technology has economically attractive features, is technically possible, and is environmentally sustainable. The existing literature has shown a significant gap of knowledge concerned with critical influence factors due to dependency such as market, institutional, and family choice for a fuel source. Some elements are the main barriers to the adoption rate for the communities of Pakistan in rural areas to accept, build and practice successful biogas plant solicitation. In Pakistan, literature has shown that some studies focus on biogas technology (Ashraf et al., 2019; Z. Wang et al., 2020). However, the main focus of these studies was merely on the adoption of biogas technology. But no one has examined why biogas technology was left by the farmers and the significant barriers compelling. Hence, the primary purpose of conducting this study was to explore and discuss the different major factors that encumber farmers to adopt biogas technology.

Moreover, we try to find out significant barriers and reasons compelling farmers to desolate the use of biogas technology. Results of this research study will support government institutions, competent authorities, and NGOs to condense the process of weaknesses. The outcomes of this study will also release and identify to the government that it is highly required to take appropriate actions to spread information and awareness on the adoption of biogas technology and start its development programs in the future. The present study investigated technical barriers and critical social factors on adopting biogas-installed plants in Pakistan. KN-RSPN (rural support programs network) report of Pakistan has installed ten biogas plants through the domestic biogas program (PDBP) in Punjab throughout project phase one, which is the maximum installed rate biogas plants.

The remaining study is organized as follows: Section 2. deliberates the formulation of hypotheses, Section 3. illustrates the research methodology, Section 4. discusses the data analysis and results of the study, Section 5. Important barriers and inspiring factors, Section 6. indicates the discussion and implication. Finally, section 7. concludes the research and provides the important limitation

2. Formulation of hypotheses

2.1 Availability of technicians for biogas plants

To overcome the blamed economic conditions due to energy inefficiencies, the establishment of biogas technology asserts dominance over energy decisions of rural areas in Pakistan. The supremacy is necessary to analyze the durables prevailing in energy efficiencies and implications of biogas technologies with durable investments. Biogas energy has massive potential and emerges as a promising RE source to fulfil the power and financial requirement of the country. Pakistan has 15 M potential of biogas power plants to run successfully, which can play a vital role in the country's economic development (Iqbal et al., 2018). The country has required experienced technicians for the biogas plants. The government has rich biogas resources, including agricultural residues, fuel-wood, municipal solid waste, and animal dung. Domestic energy needs are fulfilled by using 48% fuel-wood and 32% using animal residues and crops. Pakistan has 4800-5600 MW power potential from animal dung. Correspondingly, the potential of municipal solid waste for electricity generation through biochemical and thermochemical conversion is 220 kWh/t and 560 kWh/t, respectively (Irfan et al., 2020). Due to agricultural country, Pakistan has a considerable quantity of animal base biogas resources. The functional implementation of these biogas resources can return the fruitful outcome to the country's rural areas. The proper use of manure and straw biogas resources can play a vital role in the emission reduction effect and increase economic advantages (Gao et al., 2019). The biogas plants contribute to producing electricity, reduce the emissions level, increase economic development by increasing profit, and its upgrading can increase environmental performance (Cucchiella et al., 2019). Biogas technology adoption in rural areas can play a vital role in the economic development of the country. Its parallel situation positively depicts the biogas adoption of sites and projections that could increase economic growth. We formulated the first hypothesis in the light of these findings as follows:

H1: *There is a positive association between the availability of technicians for biogas plants and the adoption of biogas social projects in Pakistan.*

2.2 Low-cost and clear policy

The population of Pakistan is approximately 60% living in rural areas and demands energy sources for commercial and domestic use. The established portable biogas plants are advantageous due to abundant production of methane gas, low cost, clear policy and lightweight. This type of biogas plant can produce for the prosperity of rural areas and fulfill domestic requirements (I. Abbas et al., 2020). The prosperity of the rural areas has co-related with the adoption of biogas plants. The prosperity and biogas development are included household biogas digesters, biomethane plants, biogas grid plants for electricity generation, the development of large-scale biogas plants, and small-scale biogas digesters in rocky areas: the incentives, digested biogas integration, various capital investment mechanism construction, and improvement for the biogas sector (Haile et al., 2019). These findings are much consistent with the development of biogas plants initiated in Pakistan. This importance elaborates the significance of the biogas for individual investment and its association with economic prosperity. The proper utilization of biogas plants in rural areas can bring economic prosperity beyond the limits of biogas adoption. Biogas is the best RE option for the region's development and prosperity regarding a professional management unit. Finally, commercial biogas is considered the direction of revolution in rural areas and provides social benefits, economic and environmental (Zambon, 2017). Overall, biogas technology model adoption is a well-matched condition for the prosperity of rural people in Pakistan. These arguments lead us to the formulation of the third hypothesis as follows:

H2: *There is a positive association between the low-cost and clear policy and adopting biogas plants in Pakistan.*

2.3 User satisfaction and biogas plant-quality

Biogas generation is used in electricity production, and biogas waste is an eco-friendly and sustainable RE source. Electricity generation from biogas can remove power crises, waste management, and environmental issues in Pakistan. Biogas waste is one of the best energy sources become an essential component for sustainability transition and concerning emissions and economy lavishly available in Pakistan, including kitchen waste, sugarcane bagasse, poultry waste, and animal manure. The total biogas production potential is 226.8 M m^3 d^{-1} in the country, while electricity generation is 59,536 $^{GWh\ y^{-1}}$ which is 49.4% of the total power production estimated for 2018 (Yaqoo et al., 2021). The satisfaction of the users regarding the biogas plant is paramount, especially in Pakistan. The use of biogas can provide us 280MWh/day of electricity from poultry waste (Gebreegziabher et al., 2018). It helps in upbringing the livelihood of people but could also denote positive impacts on people's lives. The looking potential for biogas power projects has stated a positive share in RE. The present values of the initial investment in solar power projects have enumerated significant coverage of the amount invested.

Biogas holds massive methane produced with anaerobic fermentation of the animal dung taken by organic material. Pakistan has an excellent biogas production potential and is the sixth-largest livestock-based economy in the whole world.

The government of Pakistan (GoP) has taken initial steps to start the biogas support program (BSP) (I. Jan & Akram, 2018). Benefits gains are more extensive in the coming years than benefits gains in the first year of the biogas plant due to the fixed installation cost. In Pakistan, using rice husk, installing a biogas plant with poultry waste is feasible according to benefit-cost analysis. We proposed the third hypothesis by keeping in view these findings as follows:

H3: *There is a positive association between user satisfaction and plant quality and the adoption of biogas in Pakistan.*

2.4 Operational and maintenance government support and adoption of biogas plant

The biogas sector of Pakistan has enormous potential and needs for appropriate utilization with relevant information to the local formers. The issues of the biogas sector can be removed with the investment of foreign investors if operational and maintenance government support is provided to the biogas plant users in Pakistan. Operational and maintenance costs vary from installation scales. The adopted technical and operational design for the biogas plant should be considered for similar projects. The government can play a primary role in promoting the biogas sector in the country by offering subsidies, incentives, and current policies to attract stakeholders and investors (Jarrar et al., 2020). the fixed dome biogas plants are excellent financial performance due to low capital costs (installation and reaction), lower maintenance and operational costs, and rapid payback. (Yasar et al., 2017). The thermal energy produced with biogas positively affect evaluation outcome. The RE policy incentives can attract investors for biogas and improve biogas plants' viability if the policy is amended and independent projects are allowed as a renewable plug-in (Govender et al., 2019). In Pakistan, the biogas power plant can be benefited from the economic conditions. These conditions are potential impacts of some elements of operatonal and maintenance and close associations of improvement towards biogas power projects. In the light of these arguments, we proposed the following hypotheses as follows:

H4: *There is a positive association between operational and maintenance government support and the adoption of biogas in Pakistan.*

2.5 The moderating role of awareness and understanding between the availability of technicians and biogas plant

Awareness and understanding about biogas technology to the farmers and the rural regions are associated with positive and significant feedback toward the economy. Biogas production with the use of waste is an efficient technique. The contribution, local experts' availability, and attractiveness of biogas technology's increasing RE market are the essential factors in adaptation to climate change (Hasan et al., 2020). A clear picture is depicted in developing countries like Pakistan, where biogas production can improve with biogas technology adoption. The failed ratio of productive biogas installation is 50% due to technological and logical issues within two years after contracting. Due to the poor quality of digester feed, the lack of awareness and understanding of the facilities failed to sustain biogas production. During the shortage of primary feedstock, the local technical data to use alternatives also fails to maintain biogas production (Tumusiime et al., 2019).

The current position states the evaluation based on awareness and understanding of biogas plant, which describes the broader geographical region view. These elements are linked significantly with biogas installation and production. Some factors played a role in delaying specific biogas plants, but developing countries positively associated services with biogas plants. Acknowledging responsibility, consumer effectiveness, environmental concern, and awareness of consequences ultimately and significantly affect the farmer's norms. Subsequently, the intentions of the farmers affect through personal criteria to adopt biogas technology in Pakistan. (Z. Wang et al., 2020). In the light of these arguments, we proposed the following hypothesize as follows:

H5: *The project's awareness and understanding positively moderate the association between the availability of technicians and the adoption of biogas in Pakistan.*

H6: *The project's awareness and understanding positively moderate the association operational and maintenance government support and adoption of biogas in Pakistan.*

H7: The project's awareness and understanding positively moderate the association between the low-cost and clear policy and the adoption of biogas in Pakistan.

H8: The project's awareness and understanding positively moderate the association between user satisfaction and plant quality and adoption of biogas in Pakistan.

In this study, energy choice theory is on a theoretical basis. This study can apply the energy choice theory in a specific area. Depending on gas connection availability, an investigation will be used where it has the potential to choose between connecting with a Sui gas national or biogas from agriculture waste or other alternatives energies. The energy ladder model defined that any household has the choice to choose a specific fuel. Different types of fuels can be changed with this linear process. Traditional fuels dung cake, shrubs, and firewood on the bottom level but modern fuels such as electric stoves and methane gas depend on the household's average income. This model explicitly highlights the individual pay for explained energy choice (Gautam et al., 2020). Countries worldwide are facing challenges by using a conventional source of energy to meet the clean energy demands of their people and trying to explore new RE sources. This theory has two main factors: economic and wealth status (Ozoh et al., 2018). In Pakistan, this study was conducted based on the theoretical background to find out the adopting factors for biogas energy plants. The assumed environmental, social, and technical factors could not be excluded for the failure or success of the biogas energy plants through consumers or society. The reflection of consumer perception can deliver through the theoretical framework figure 1 to the choice of energy source for living.

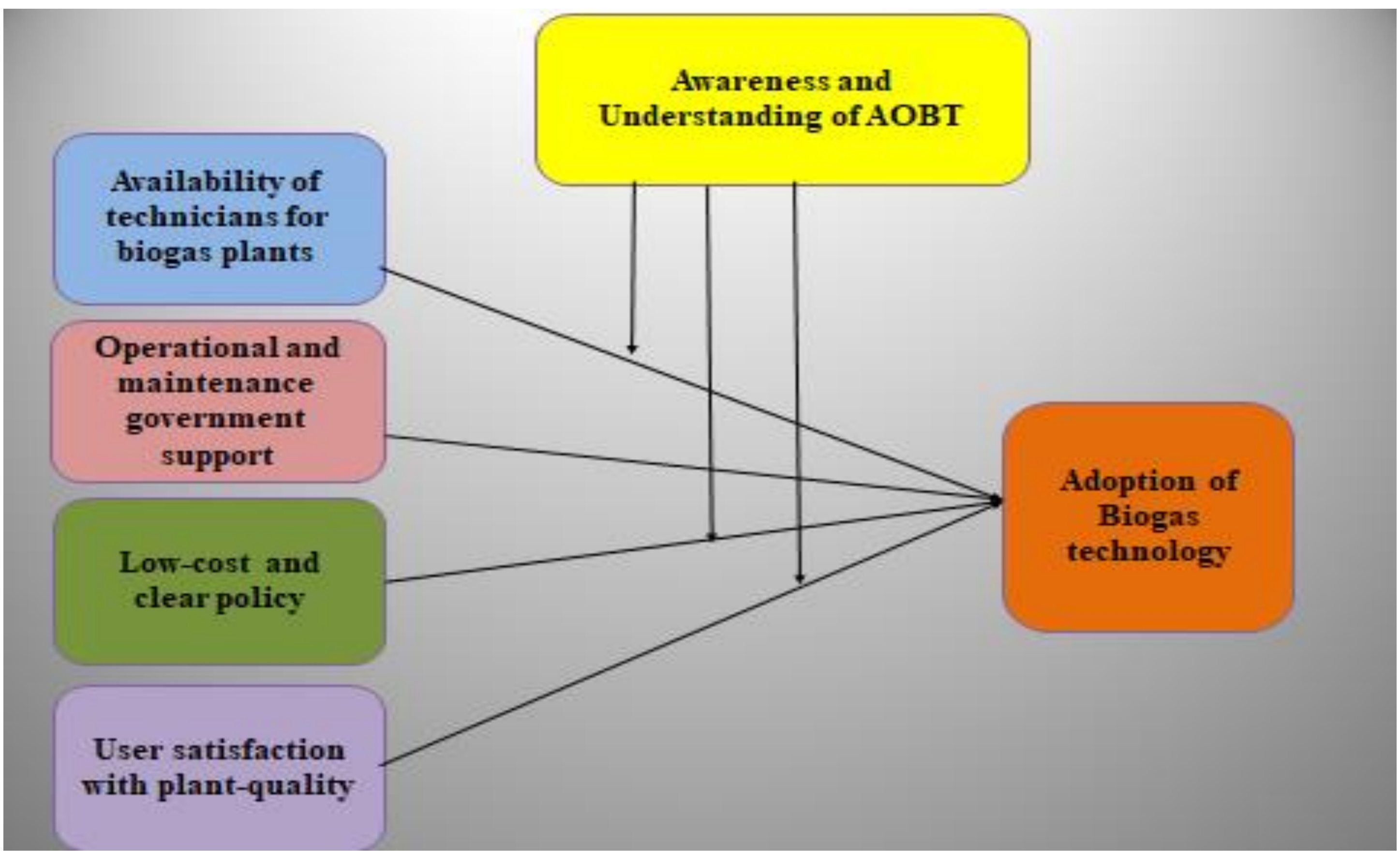

Figure 1: Conceptual Model

3. Research methodology

This research has used non-probability (snowball) sampling to improve biogas plants and to check the potential of biogas in Pakistan. Currently working biogas plants were selected as a part of research to improve their service and quality. Specific biogas plants were adopted when the snowball sampling technique was employed to present our sample from biogas plants throughout the country. To fulfill this purpose, the researchers surveyed from march to September (2021); when the fourth wave named delta variant virus, a type of coronavirus (COVID-19), was at its peak in Pakistan, it was a high risk to approach relevant respondents. Moreover, all representatives have a heterogeneous background in using biogas plants as well as demographic measures. Furthermore, snowball sampling was employed to select respondents in this research from Pakistan, involving respondents with diverse behaviors. The ongoing research goal is to examine the potential and barriers to adopting biogas technology and assess satisfied owners of biogas plants with their financial performance. Examine the moderating role of awareness and understanding in adopting biogas plants are among nexus of satisfaction and reduce the barriers. The present study has adopted the quantitative approach of data collection and the questionnaires to collect the data from the respondents. The respondents were selected from Pakistan based on snowball sampling and questionnaires sent using mobile applications.

3.1. Sample and procedure

This study was conducted in Pakistan based on biogas plants. We contacted 79 biogas plants owners and users from 35 villages, of which 63 are agreed to participate in the survey. Primary data was collected by using snowball or non-probability sampling techniques. The data collection process was started with a few numbers of respondents. After that, it was increased progressively. After getting the consent of biogas plant owner-users, the researchers provided opened and closed hand questionnaires using a smartphone to each user biogas plant via LinkedIn and WhatsApp. This research questionnaire was applied after initial site visits, interviewing biogas users, considering existing literature, and discussion with an expert. Lastly, 56 filled questionnaires were returned from the total sample size of the questionnaire survey. However, the researchers discarded 5 questionnaires due to unmatched and inadequate responses. There are a few participants in this study; that's why the snowball sampling technique was used. This process leads the researcher to attend to the respondents who are still undiscovered. Finally, the sample resulted in 51 useable responses from the overall sample size, and the response rate was 80.95 percent. The respondents collected personal data from the researcher's resources and respective village people. The finding is generated based on a fair sample representation, and PLS-smart was used for data analysis.

The respondents' demographic features include (gender, age, and owner's experience, owner's education, and biogas plant names currently working). The respondents were provided with the proper response in this study (see table 1). The present research has followed the standard 5-category scale in which one symbolizes always, and five expresses as never: The first section of the questionnaire covers the personal detail of the respondents, while the second section of the questionnaire is related to the features of biogas plants, like quality, user satisfaction, biogas plant cost, and energy supply. The present study has adopted six predictors such as availability of technicians for biogas plants (AT) with six items, the operational and maintenance government support (OMGS) with five things, the user satisfaction and plant-quality (USPQ) with five things, the low-cost and clear policy (LCCP) with seven things, user satisfaction and plant-quality with five things and adoption of biogas technology (ABT) as a dependent variable with eight items and finally awareness and understanding of (AUAOBT) as moderator variable with six items. These variables with links are shown in table 3. The goal was to gather responses from the biogas plant users on three critical points at the time of investment in a biogas plant, i.e., operational matters and maintenance, technical and skilled labor, and day-to-day operational tools used in biogas plants. In this study, a new research questionnaire was developed and tested before applying by the author. The first part of the questionnaire covers the satisfaction of biogas plants users.

In contrast, the second part of the online questionnaire is related to the investment of biogas plan and the most favorable scenario for the satisfaction of biogas plant users. These questionnaires were sent online to owners of biogas plants with enough knowledge about biogas plants' operation. This part also includes the operational and maintenance cost of biogas plants and day-to-day plant expenses. Besides, the third part of the questionnaire is related to the technical and skilled labors and trained owners of biogas plants. This study also used secondary data that was collected through research studies and some existing published reports.

Table 2. Demographic profile.

Variables	Characteristics	Frequency	Percentage
Gender	Male	44	86.27
	Female	7	13.5
Age	Less than 25	3	5.9
	26-30	7	13.5
	31-40	11	21.56
	41-55	13	25.45
	56-65	10	19.60
	65 and above	7	13.5

Owner's education	Under metric	18	35.29
	Metric	9	17.64
	Faculty of Arts	11	21.56
	Bachelor	7	13.5
	Master	6	11.76
Owner's experience	1-2 years	21	41.17
	3-4 years	11	21.56
	5-6 years	7	13.5
	7-8 years	5	9.8
	9-10 years	3	5.9
	11- and above	4	7.8
Biogas plant names, currently working	**Floating drum**		
	A mild-steel gas storage drum	9	17.64
	inverted over the slurry	8	15.68
	Fixed drum		
	Chinese fixed-dome plant	7	13.5
	Janata model	12	23.52
	Deenbandhu	9	17.64
	Camartec model	6	11.76

3.2 Instrument and variables measurement

Researchers have adopted all items from different previous literature in this research. Items based on the availability of technicians for biogas plants were constructed from the study (Shahzad et al., 2020). Things regarding the operational and maintenance government support were adopted from this research study (Afridi & Qammar, 2020). Items related to the low-cost and clear policy were assumed from (Słupek et al., 2020). Objects related to user satisfaction and plant quality were constructed (Berhe et al., 2017). Items that belong to the awareness and understanding of AOBT were adopted (Z. Wang et al., 2020). And finally, items related to the adoption of biogas technology were adopted from this study (Uhunamure et al., 2019). Two professional translators first translated all items adopted from the previous studies into the local language, i.e., Urdu. After that, another translator converts these statements into English from the local language, given the suggestion of (Brislin, 1970). There were no significant differences found in the translation, but a few grammatical mistakes ascended, which were resolved. Finally, questionnaires for data collection were distributed in the home-grown language.

4. Data analysis and results

Our research employed the structural equation modelling (SEM) method for data analysis objectives (Irfan et al., 2021). The study adopted this method to analyze the relational dimensions because it is a component-focused method (Sharma & Kim, 2010). PLS-SEM has frequent usage and appropriateness; that's why the author adopted it in this study; the subsequent studies are evidence (Ying et al., 2020). Structural equation modelling (SEM) is more advantageous than other methods of traditional statistical analysis. It is helpful for statistical analysis regarding efficiency, convenience, and accuracy (Franziska et al., 2016). SEM covers the problems of first-generation analysis, but it is a second-generation technique. SEM can assist in analyzing abundant variables at the same time because it is a multivariate analysis process. SEM is continuously popular in business research because it can simultaneously deal with complex and multiple relationships (Chin & Newsted, 1999). Variance-based SEM (VB-SBM) or partial least square (PLS)-SEM and covariance-based SEM (CB-SBM) are two well-known techniques of SEM (Henseler et al., 2009). The inappropriate adoption of analytical methods can cause inaccurate conclusions; on the other hand, an appropriate statistical technique is most important for management and social science research (Ramayah et al., 2010). Measurement and structural models are two-stage analysis approaches of PLS-SEM that include measurement results in two steps (Osborne, 2010). Reliability and validity tests or the assessment of the inner model is included in the measurement assessment model. Hypotheses/relationships testing or the evaluation of the outer model is included, structural assessment model. The present research used PLS 3.0 software for primary data analysis and examined the links among the understudy variables. Additionally, partial least square path modeling has higher statistical power than covariance-based structural equation modeling. PLS-SEM is more advantageous to intercept relationships among the variables.

In addition, the smart-PLS for variance-based structural equation modeling (SEM) using the partial least squares (PLS) path modeling method to examine the nexus among the variables (Solangi et al., 2019). The purpose of smart-PLS is to hypothesis testing in the research, and the complex model research has adapted to it. The smart-PLS has two approaches measurement assessment model and structural model for the analysis. The assessment measurement model includes the reliability and validity of the constructs checked with convergent and discriminant validity. The convergent validity related to the correlation among the items examined using the Chronback Alpha, composite reliability, and items loading. However, the discriminant validity is associated with the correlation among variables examined using Fornell Larcker, cross-loading, and heterotrait monotrait ratio. Also, the assessment of the measurement model includes the testing of hypotheses that are reviewed using path analysis—the analysis of the study discussed in the findings section. The path analysis has shown the links among the variables. All verified validity and reliability values in this measurement model are given below in tables 3, 4, and 5. The measurement assessment model shows in figure 2, which indicates factor loading of the variables. All the factor loading values are more significant than (0.50), so the convergent validity of all items is valid in the measurement assessment model. The path analysis has been shown to test the hypotheses, and the results have shown that AT, AUAOBT, and LCCP are positive.

In contrast, OMGS has a negative association with ABT and accepts AT, AUAOBT, LCCP and USPQ. In addition, the results also show that the AUAOBT significantly moderates among the links of AT, AUAOBT, LCCP, USPQ, and ABT and accept AT, AUAOBT, LCCP, and USPQ. This section provides the analysis of convergent validity that shows the correlation among items. The figures show that the loadings and AVE values are higher than 0.50, while Alpha and composite reliability (C.R.) values are more significant than 0.70. These values have indicated that convergent validity is the valid and high connection among the items. The results of the research also include the assessment of correlation, among things named convergent validity. The figures highlighted that the factor loadings are more significant than 0.50, Alpha values are more than 0.70, AVE values are also higher than 0.50, and composite reliability (C.R) values are also greater than 0.70. These values have indicated a high correlation among items and valid convergent validity. The results and links are reporting in table 3.

4.1 Measurement assessment model

In the present research, measurement model evaluation is required to conduct reliability and validity tests for all the given constructs. The measurement model confirms the reliability and validity of the constructs, the factor loadings of all items were approved by the model (Joseph F. Hair et al., 2019). The measurement evaluation model is consistent on reliability tests (item reliability and internal consistency reliability) and validity tests (convergent validity and discriminant validity) (Joe F Hair et al., 2011). Convergent validity was measured over the average variance extracted (AVE), internal consistency reliability was measured over composite reliability (C.R.), and item reliability was measured over outer loading. All item loadings are well upstairs with the threshold value of 0.5 (Jr et al., 2014); see table 3. The analysis of the study verified that all of the averaged factor loadings were greater than 0.50, and each observation contributed to the constructed variable (Arbuckle, 2011) AVE exceeds the suggested value of 0.5. The composite reliability value for each standard exceeds the cut-off point of 0.7, which displays that the measurements are reliable (Anderson & Gerbing, 1988). The results of the present research designate that all the values of AVE are between 0.570 (adoption of biogas technology) and 0.871 (low-cost and clear policy), C.R. values are between 0.913 (adoption of biogas technology) and 0.979 (low-cost and clear policy). The values of all additional loadings are between 0.5 and 0.946.

Table 3. Convergent Validity.

Items	Loadings	Alpha	CR	AVE
ABT1	0.588	0.890	0.913	0.570
ABT2	0.797			
ABT3	0.793			
ABT4	0.646			
ABT5	0.808			
ABT6	0.794			
ABT7	0.788			
ABT8	0.795			

AT1	0.834	0.893	0.919	0.655
AT2	0.856			
AT3	0.699			
AT4	0.763			
AT5	0.835			
AT6	0.856			
AUAOBT1	0.953	0.959	0.968	0.834
AUAOBT2	0.829			
AUAOBT3	0.952			
AUAOBT4	0.954			
AUAOBT5	0.827			
AUAOBT6	0.954			
LCCP1	0.930	0.975	0.979	0.871
LCCP2	0.946			
LCCP3	0.936			
LCCP4	0.940			
LCCP5	0.944			
LCCP6	0.901			
LCCP7	0.936			
OMGS1	0.912	0.920	0.936	0.745
OMGS2	0.891			
OMGS3	0.853			
OMGS4	0.859			
OMGS5	0.798			
USPQ1	0.861	0.922	0.941	0.762
USPQ2	0.872			
USPQ3	0.880			
USPQ4	0.886			
USPQ5	0.864			

The findings of the research also include the assessment of correlation among variables named as discriminant validity. The cross-loading were used to test the discriminant validity. These values have indicated a low correlation among variables and verify discriminant validity. The bold values in table no. 5 show that all factors have a strong relationship but weak relationships with other factors. The bold values of the cross-loadings table are compared with other factors row-wise to check discriminant validity. The findings section has also shown in table 4 the discriminant validity through fornell larcker about the nexus among the variables. The figures have shown that the values indicated the nexus with the variable itself are higher than those with other variables. These values explored that discriminant validity is the valid and low connection among the variables. All the values are highlighted in table 4 and table 5. The measurement assessment model shows in figure 2, which indicates factor loading of the variables. All the factor loading values are more significant than (0.50), so the convergent validity of all items is valid in the measurement assessment model.

Table 4. Fornell Larcker analysis.

Vriables	ABT	AT	AUAOBT	LCCP	OMGS	USPQ
ABT	0.755					
AT	0.508	0.809				
AUAOBT	0.504	0.823	0.913			
LCCP	0.472	0.496	0.498	0.933		
OMGS	0.173	0.176	0.172	0.336	0.863	
USPQ	0.393	0.425	0.378	0.415	0.166	0.873

Notes: *N =51*; AT = availability of technicians for biogas plants; OMGS = operational and maintenance government support; LCCP = low-cost and clear policy; USPQ= user satisfaction and plant-quality; AU = awareness and understanding of AOBT; ABT= adoption of biogas technology

Table 5. Cross-Loadings.

Vriables	ABT	AT	AUAOBT	LCCP	OMGS	USPQ
ABT1	**0.588**	0.305	0.278	0.354	0.206	0.187
ABT2	**0.797**	0.456	0.493	0.397	0.124	0.319
ABT3	**0.793**	0.459	0.446	0.426	0.095	0.359
ABT4	**0.646**	0.261	0.244	0.330	0.145	0.233
ABT5	**0.808**	0.447	0.382	0.398	0.144	0.315
ABT6	**0.794**	0.358	0.398	0.304	0.124	0.284
ABT7	**0.788**	0.373	0.359	0.319	0.090	0.340
ABT8	**0.795**	0.351	0.377	0.305	0.146	0.297
AT1	0.400	**0.834**	0.663	0.388	0.180	0.327
AT2	0.453	**0.856**	0.731	0.450	0.134	0.355
AT3	0.364	**0.699**	0.536	0.317	0.104	0.341
AT4	0.394	**0.763**	0.663	0.398	0.124	0.348
AT5	0.396	**0.835**	0.662	0.382	0.179	0.330
AT6	0.450	**0.856**	0.723	0.455	0.134	0.363
AUAOBT1	0.457	0.766	**0.953**	0.457	0.172	0.330
AUAOBT2	0.470	0.720	**0.829**	0.442	0.134	0.372
AUAOBT3	0.460	0.759	**0.952**	0.460	0.168	0.333
AUAOBT4	0.448	0.774	**0.954**	0.461	0.175	0.331
AUAOBT5	0.466	0.718	**0.827**	0.444	0.126	0.372
AUAOBT6	0.450	0.764	**0.954**	0.456	0.165	0.327
LCCP1	0.425	0.456	0.465	**0.930**	0.335	0.383
LCCP2	0.446	0.472	0.457	**0.946**	0.312	0.403
LCCP3	0.423	0.476	0.450	**0.936**	0.300	0.410
LCCP4	0.436	0.463	0.473	**0.940**	0.332	0.379
LCCP5	0.450	0.468	0.462	**0.944**	0.313	0.398
LCCP6	0.467	0.447	0.471	**0.901**	0.288	0.359
LCCP7	0.434	0.456	0.469	**0.936**	0.317	0.378
OMGS1	0.225	0.213	0.199	0.331	**0.912**	0.173
OMGS2	0.145	0.162	0.162	0.293	**0.891**	0.162
OMGS3	0.111	0.069	0.102	0.301	**0.853**	0.110
OMGS4	0.091	0.123	0.096	0.275	**0.859**	0.118
OMGS5	0.081	0.129	0.122	0.208	**0.798**	0.118
USPQ1	0.338	0.309	0.292	0.354	0.126	**0.861**
USPQ2	0.351	0.389	0.342	0.357	0.130	**0.872**
USPQ3	0.329	0.373	0.306	0.351	0.146	**0.880**
USPQ4	0.318	0.376	0.345	0.370	0.189	**0.886**
USPQ5	0.370	0.403	0.361	0.375	0.136	**0.864**

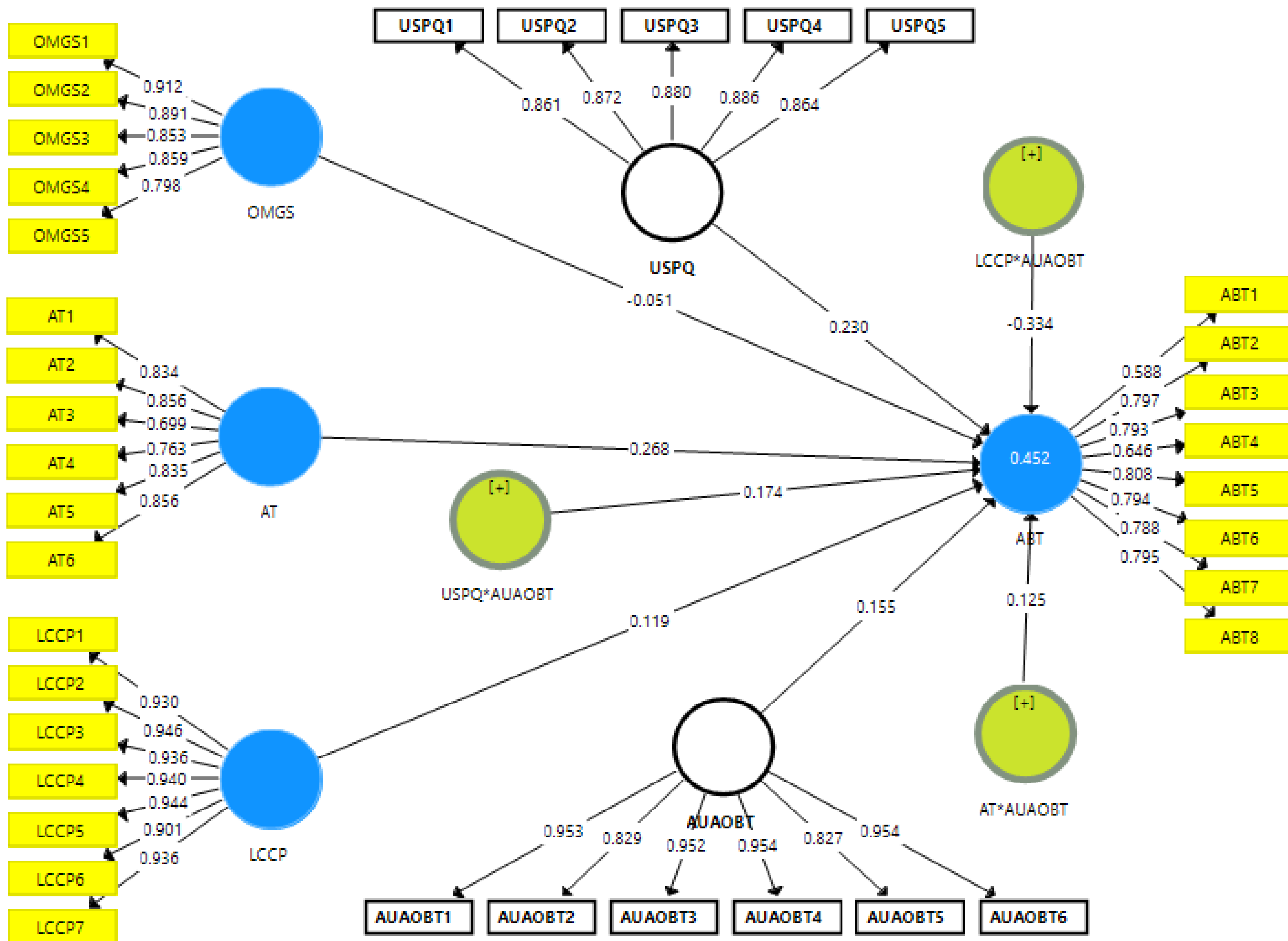

Figure 2. Measurement model assessment.

The heterotrait-monotrait ratio of correlations (HTMT) for discriminant validity measure is considered more suitable due to different researchers' criticism on the criteria of Fornell-Larcker (Akbar et al., 2019). The value of discriminant validity is confirmed if it is less than 0.85 (Cohen, 1988) or 0.90 (Irfan et al., 2021). All values are less than 0.90 in table 6. The findings section has also shown the discriminant validity that is about the nexus among the variables. The figures have shown that the values indicated the nexus with the variable itself are higher than those with other variables. This research also used the heterotrait monotrait (HTMT) ratio to examine the correlation among variables. The statistics of HTMT have been shown that the values are less than 0.85.

Table 6. Discriminant validity Heterotrait–Monotrait (HTMT).

Vriables	ABT	AT	AUAOBT	LCCP	OMGS	USPQ
ABT						
AT	0.559					
AUAOBT	0.535	0.786				
LCCP	0.504	0.528	0.514			
OMGS	0.172	0.176	0.167	0.342		
USPQ	0.427	0.468	0.400	0.437	0.170	

Notes: *N =51*; AT = availability of technicians for biogas plants; OMGS = operational and maintenance government support; LCCP = low-cost and clear policy; USPQ= user satisfaction and plant-quality; AU = awareness and understanding of AOBT; ABT= adoption of biogas technology

4.2. Structural assessment model

First, we evaluated the measurement model, and then the structural assessment model was evaluated, which checked the relationship between exogenous and endogenous variables. The assessment of the structural model is based on different types of statistical values, including effect size (f^2), t values, predictive relevance (Q^2), coefficient of determination (R^2), and path coefficient (β values). The study evaluates hypotheses and estimates the significance of path coefficients using the criteria provided in the PLS-SEM literature. The bootstrapping process was employed with 5000 sub-samples with a 5% significance level (one-tailed) to test the significance of the hypotheses. Results indicate that all hypotheses are accepted except H6. Availability of technicians for biogas plants ($\beta = 0.268$, $t = 2.909 > 1.64$, $p < 0.05$), availability of technicians for biogas plants relationship (moderator), ($\beta = 0.230$, $t = 4.050 > 1.64$, $p <0.05$), awareness and understanding through AOBT ($\beta = -0.125$, $t = 1.870 > 1.64$, $p < 0.05$), low-cost and clear policy, ($\beta = 0.155$, $t = 1.874 > 1.64$, $p < 0.05$), low-cost and clear policy relationship (moderator), ($\beta = 0.334$, $t = 5.077 > 1.64$, $p <0.05$), user satisfaction and plant-quality, ($\beta = 0.119$, $t = 1.695 > 1.64$, $p < 0.05$), user satisfaction and plant-quality relationship (moderator), ($\beta = 0.174$, $t = 3.125 > 1.64$, $p <0.05$, operational and maintenance government support ($\beta = -0.051$, $t = 1.090> 1.64$, $p < 0.05$), have a positive significant for adoption of biogas technology.

The R^2 value of the availability of technicians for biogas plants through AOBT is 0.478, which displays that the model has substantial explanatory power for adopting biogas technology in Pakistan. However, only based on the value of R^2 is not considered a suitable and effective method to assist a model. Consequently, the measurement of predictive relevance Q^2 of the model is the best way. The latent exogenous standards have excessive predictive relevance, which shows that the value of Q^2 is sophisticated than zero. The model has significant predictive relevance because the results show that the value of Q^2 is 0.248, which suggests increasing the small-scale industry's performance through SHS. These are the typical values of f^2, including 0.02, 0.15, and 0.35, which indicate in three categories small, medium, and large, in effects, respectively. Thus, the value of f^2 assumed that effect size differs from medium to large (see table 7). Table 6 has several kinds of statistical techniques. The structural assessment model shows in figure 3, which indicates the significant relationship among the variables because the T- values are greater than (1.64). All hypotheses are accepted except H5. All the values of moderated variables are positive signs and indicate an entirely significant relationship in the structural assessment model for the adoption of biogas technology in Pakistan.

Table 7. Structural model results (hypotheses testing).

Hypothesis	Relationships	Beta	S.D.	T Statistics	P Values	Supported	R^2	Q^2	f^2
H1	AT -> ABT	0.268	0.092	2.909	0.002	Yes	0.478	0.248	0.093
H2	AUAOBT -> ABT	0.125	0.067	1.870	0.032	Yes		0.167	0.037
H3	LCCP -> ABT	0.155	0.083	1.874	0.032	Yes			0.110
H4	USPQ -> ABT	0.119	0.070	1.695	0.047	Yes			0.017
H5	OMGS -> ABT	-0.051	0.046	1.090	0.139	No			0.019
H6	LCCP*AUAOBT -> ABT	-0.334	0.066	5.077	0.000	Yes			0.021
H7	AT*AUAOBT -> ABT	0.230	0.057	4.050	0.000	Yes			0.013
H8	USPQ*AUAOBT -> ABT	0.174	0.056	3.125	0.001	Yes	0.489		0.016

Notes: *N =51*; AT = availability of technicians for biogas plants; OMGS = operational and maintenance government support; LCCP = low-cost and clear policy; USPQ= user satisfaction and plant-quality; AU = awareness and understanding of AOBT; ABT= adoption of biogas technology.

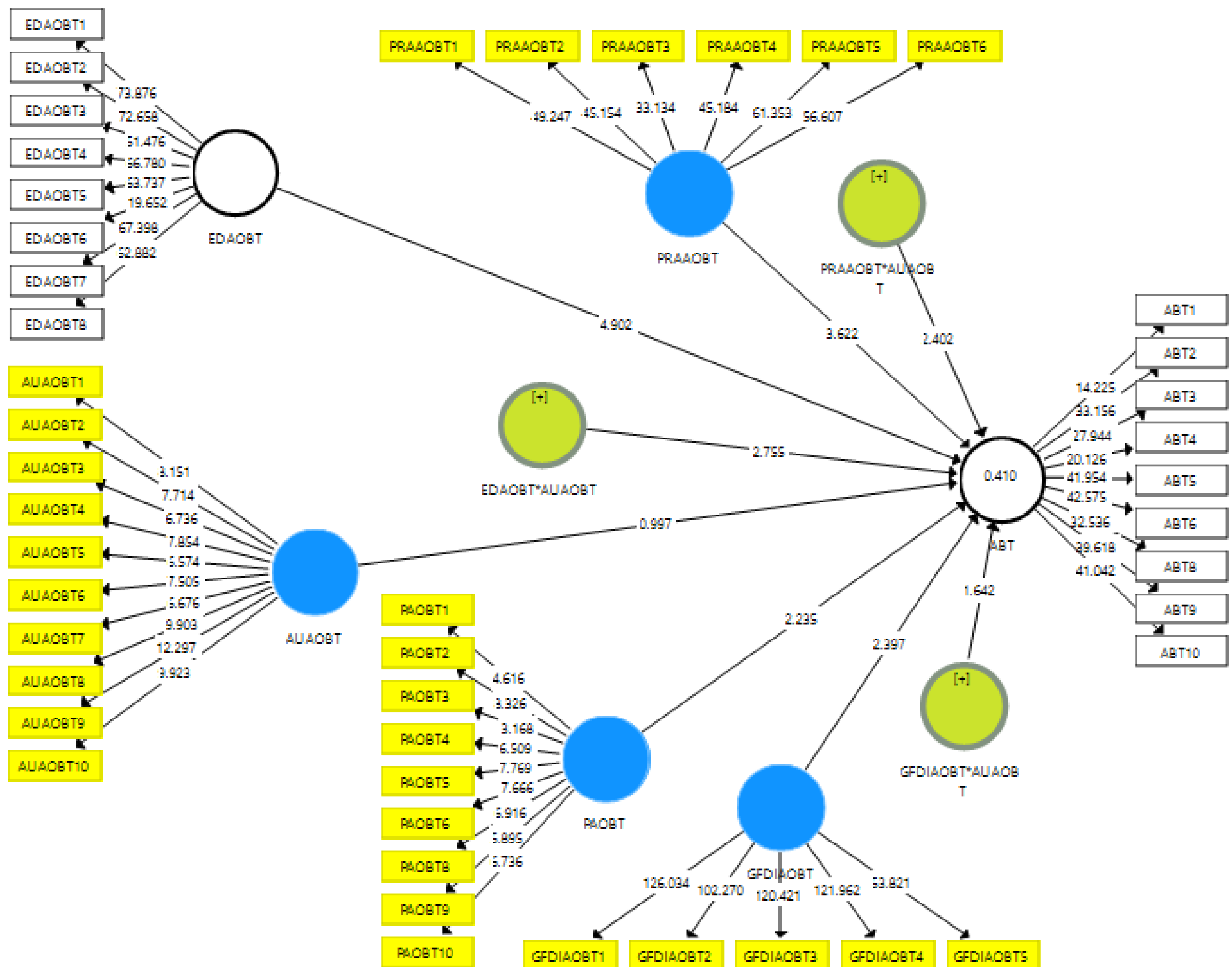

Figure 3. Structural model assessment.

The structural assessment model indicates the relationship of the variables because the T- values are more critical than (1.64). The adoption of biogas technology is positive and significant for the availability of technicians for a biogas plant in Pakistan. All the values of moderated variables have positive signs. They indicate an entirely substantial relationship in the structural assessment model for adopting biogas technology to attract green FDI in Pakistan.

Table 8. Satisfaction and views of biogas plant users.

Description	Cases (%)	Responses (%)	Frequency
Food is cleaner and tastier prepared in biogas	10.8	6.4	6
Preparation of appliances	4.9	3.2	3
Workload reduction	8.9	5.3	5
Cooking made easy	6.1	4.2	4
Easy biogas plant operation	12.8	7.3	7
Food preparation & lighting (sufficient gas)	14.7	8.5	8
Technicians' availability	20.6	11.6	11
Advantages of health	6.9	4.3	4
Advantages of economics	12.9	7.4	7
Advantages of environment	8.9	4.3	5
Reputation in society	10.9	6.4	6
Others	12.9	7.4	7

Table 8 demonstrates the satisfaction and views of respondents from Pakistan for their biogas plants. The primary reasons are the easy operation of biogas plant, availability of technicians, economic advantages, sufficient gas collection for food preparation, gas used in lighting, and social reputation. The countries such as India, Nepal, and Bangladesh have technical service availability as a sufficient driving force for social projects development generally (Breitenmoser et al., 2019). 64% of respondents said that adopting biogas technology needed user satisfaction with a biogas plant in Pakistan. 21% of respondents are expressed that a low-cost and straightforward policy is required for biogas technology, but 15% of the respondents disclosed that user satisfaction and plant quality are also necessary. In excess half of biogas plants, user respondents reported that their plants are functional and serviceable.

5. Important barriers and inspiring factors

The partial adaption of biogas plants is facing a list of various discouraging factors. Unavailability of technicians has the highest response attributed to 16.8% while frequent operational problems were 13% and low pressure of biogas is another problem. Many operational problems are facing by the biogas plants, such as deterioration of the steel parts, roof and walls crack development of the biogas plants, and leakages of the gas pressure (Haile et al., 2019; Scheutz & Fredenslund, 2019). The lowest pressure of biogas was 4.9% which is a severe issue to food for well cooking. Poor mixing in feed is the main reason for the low pressure or biogas inside the reactor. The mechanism was stirring in biogas plants to improve the requirement of gas pressure for the facilitation of end-user (Nsair et al., 2019). The complete dissatisfaction is indicated in the second section of the table by the plant owners. The frequent technical problems are the reason to delay the operation of the biogas plant, about which 21% of the owners complained. Correspondingly, to handle the biogas plant, the extra workload was 15%, gas leakages were 13%, and technical support is equal to zero for biogas consumers. The users of biogas plants feel failure and discouragement due to the contribution of these factors. The week's approval of technicians is attributed to the project to the policy framework.

The sustainability of a biogas plant project negatively affects without a supporting system and technical assistance running in the background (Pandyaswargo et al., 2019). The general problems include poor operation that linked 40% including less or more water and dung. The case percentages 8%, 6%, and 4% and lower response percentages 3%, 2.7%, and 1.8% are the attachment of poor service, bio-slurry management issues, and un-sacred toilet during installation, respectively.

Table 9. Barriers and challenging factors

Variables	Description	Cases (%)	Responses (%)	Frequency
Reasons through which users are not fully satisfied with biogas plant	Insufficient gas to prepare food/lighting	7	9	12
	Unavailability of technicians	9	11.7	16.7
	Technical problems encounter frequently	7	9	8
	Through extra workload	5	6.3	8.8
	Biogas plant operational difficulty	3	3.7	4.9
	Prepared food (not pleasant)	7	8	11.9
	Others	5	6.3	8.9
Uncontrolled reasons for biogas plant	Complete work stops occasionally	7	6.5	12.8
	To prepare food/lighting gas is Insufficient	8	8.4	14.7
	Unavailability of technicians	9	9.5	16.7
	Technical problems encounter frequently	11	11.5	19.8
	Through extra workload	8	8.4	14.5
	Food is not tasty prepared in biogas	7	7.5	12.5
	Gas leakage difficulty	7	8	11.9
	Stove's malfunctioning	5	5.3	8.7
	Others	9	9.5	16.8
Main problems or common reasons of a biogas plant to work failure	Poor material applied for Construction	9.5	7.5	18.5
	During installation poor service	5	3.4	8.7
	Old/outdated design	10	7.6	18.7
	Management issues as bio-slurry	4	3.2	6.9
	Workload increasing	8	5.2	14.7
	Poor maintenance	14	10.5	26.5

spare parts unavailability	11	8.4	20.7
Stove's malfunctioning	5	5.3	8.7
Empower local gas distribution authority in case availability of natural gas	7	5.4	12.8
Unavailability of the skilled operator of biogas plant	12	9	22.7
Poor operation with unbalanced Feed of water and dung	20	15.6	40.3
Natural disaster	10	7.7	18.7
Un-sacred attachment toilet	3	2.5	4.9
Bio-slurry obstruction in pipeline	11	8.4	20.7
condensed water made blockage of the pipeline	10	7.7	18.7
Others	16	16.9	30.5

6. Discussions and implications

The financial benefits of biogas technology are also evaluated in this study. 58% of respondents agree that they saved fuel expenditure, whereas 42% of respondents did not agree with this view of point. In recent studies, low-, middle-income countries reported fuel cost savings (Negri et al., 2020). Additionally, 38% of respondents reported a positive change in their household financial status after biogas plant installation, while 53% of respondents had no change in their financial situation. So, here this change is a feature to the number of family members and their expenditures. Joint families tend to save less, while nuclear families kept more in rural Pakistan and supported each other by contributing equally. 53% of families could not hold their money due to above mention reasons. The fully satisfied users have significantly reduced their expenditures after the installation of a biogas plant. The reduction of expenses is considered a primary adaptive reason for the satisfaction of partially satisfied users at a specific point. The biogas plant can solve and improve the household's financial status indicated by this variable. Adapter for the environment has the significant benefits of cleanliness and fitness after installing biogas plant and working in a fire accident as a substantial drop, free from illness correlated with deficiency of black kitchen or dirt in-house and smoke. A significant decrease in fire accidents was highlighted by 33% of respondents. Freedom from sickness was reported 15% correlated with deficiency and smoke of black dirt in kitchen and house, and 9% decided to reduce everyday expenditures associated with fitness in response to the question. But the main benefits of biogas plants are connected with cleanliness and healthiness. 43% of respondents were not responded to the question.

Our research findings offer valuable insights to rural people and government/ NGOs working in Pakistan. The study suggests that biogas plants are very suitable for the rural areas of Punjab Pakistan to save their expenditures, to make prosperity and economic development in these areas of Punjab. With the simultaneous implementation of biogas plants, the government and NGOs should begin with motivation and complete information about the installation process to encourage rural people and their prosperity. The results also suggested that the adoption of biogas plants has positive and significant relationships with the availability of technicians and user satisfaction with plant quality in Pakistan. The owners of biogas plants are required to complete operational guidelines for biogas plants to reduce their financial expenditure from the output of plants. Moreover, the study findings demonstrate that skilled and trained owners get more financial and maintenance benefits than non-skilled/untrained owners. The study also explored that biogas plants are more beneficial if technicians and equipment are fully available. We also suggest that the government of Pakistan, INGOs/NGOs should improve the potion of subsidies for biogas plants and economic development for the home-grown farmers. Most of the problems can solve if one individual from the family of biogas plant owners is trained and can handle the maintenance issues to save their day-to-day expenditures. The study suggested that biogas plants should be spread to other districts of Punjab rather than Faisalabad with the government's support, INGOs/NGOs.

7. Conclusion and limitations

The globally well accepted and powerful source of RE is considered biogas. But Pakistan and other low-income countries biogas has not received due to boosting rate. Although the government of Pakistan and some relevant INGO/NGO are trying to make acceptable said technology by giving subsidies for biogas plants to home-grown farmers, the acceptance ratio is meagre in rural areas and village communities. According to the choice theory of energy, the populations of this research area expressed their interest in utilizing the biogas in native farms instead of in modern ways. Conversely, the main issue of biogas plants was maintenance and operation. The major inspiring causes behind the installation and construction of biogas plants include motivation from structure, social subsidy advantages, cases of existing biogas plant owners, and protection of energy. Although, the significant reasons commonly include extra workload, gas leakages from connections, Insufficient gas to prepare Food/lighting, complex biogas plant operations, technical problems, and unavailability of technicians.

Finally, the buyers did not facilitate the services after-sale from the construction and installation organizations or bodies. Therefore, some recommendations are given to the Pakistani government to develop and promote biogas technology in rural areas of Pakistan. Government should be planning a clear policy for short courses for operation, capacity building sessions, technical support, and launching a media complaint about maintenance to develop biogas plants. The rural area of Pakistan has great potential for biogas technology to overcome domestic energy shortages. Consequently, some training steps should be taken by the relevant NGO/INGO and the government of Pakistan for sustainable project development, maintenance, and smooth operation of biogas plants in the rural areas. Hence, government institutions of Pakistan and relevant INGO/NGO should be arranged skilled technicians, technical centres and provide the appropriate installation of biogas plants to the consumer after-sales service.

Declarations

- **Ethics approval and consent to participate:** Not applicable
- **Consent for publication:** Not applicable
- **Availability of data and materials:** All data generated or analyzed during this study are included in this article.
- **Competing interests:** The authors declare that they have no competing interests.
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- **Authors' contributions: S. Ali:** Conceptualization, writing-original draft, formal analysis, data handling, and methodology. **Q. Yan:** Supervision, funding acquisition. **R.M. Elavarasan:** Writing-review and editing, **M. Irfan:** Writing-review and editing, variable construction. **K.R. Abbasi:** Writing-review and editing**, C. Işik:** Writing-review and editing.

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