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Evaluating Barriers on Biogas Technology Adoption in China: The Moderating Role of Awareness and Technology Understanding

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Biogas technology adoption is a challenge in developing countries like China. The primary objective of this study was to explore the major issues for farmers in adopting biogas plants. The sample size was identified through the snowball sampling method. A total of 51 respondents of biogas plant adopters participated in this study. The structured questionnaire was used to collect primary data through respondents. The formulated suppositions were assessed by partial least square structural equation modeling (PLS-SEM). The results indicated that all independent variables are significant and positively correlated with adopting biogas technology, reducing energy crises, and attaining cost-saving purposes. The results further indicated that the low cost and clear policy positively and significantly attract farmers to adopt biogas plants. The selected variables and their adopted moderation have a significant and positive impact on this conceptual model. The findings further indicate that major maintenance and day-to-day operations of biogas plants are expensive due to a lack of skilled operators, untrained or partially trained owners, and the unavailability of technicians. The results suggested that the government needs to plan a clear policy, provide short operation courses and technical support with skilled technicians to biogas plant owners, and launch a media campaign about maintenance to develop biogas plants.

Keywords: renewable energy, biogas resources, biogas power plants, trade using biogas technology, potential and barriers

INTRODUCTION

In the present world, human activities, including burning fossil fuels (coal and oil), are known as the primary causes of global warming (Xie et al., 2022). Like an underdeveloped world, China needs substantial energy to support its population and industry (Fang et al., 2022). China has abundant potential in the geographical location of all types of renewable energy sources like bio-energy, solar energy, and wind energy (Jinru et al., 2021). The country has the massive potential for biomass generation to produce bio-energy by applying combustion, trans-esterification, gasification, and pyrolysis (Wu et al., 2021). Modern technology can play an important role in sustainable economic

TABLE 1 | Factors motivating farmers' attention.

Reason	Case (%)	Response (%)	Frequency
Motivation by the construction body	32	11	18
Motivation by existing plants	42	15	22
Subsidy	42	14	22
Unavailability of alternative fuels	21	8	11
Environmental advantages	19	6	8
Health advantages	15	5	10
Time-saving benefits	30	11	16
Energy-saving ability	31	10	15
Social reputation	32	11	17

development in the country (Irfan and Ahmad, 2022). The fact about social niche starts with the behavior of individuals, and existing social practices are connected with it. **Table 1** indicates the reasons for inspiration to adopt biogas plants from plant users.

Some barriers and important factors closely discourage the country's acceptance rate of biogas technology. Biogas technology is still not socially acceptable in China, even though this technology has economically attractive features, is technically possible, and is environmentally sustainable. The existing literature has shown a significant gap in knowledge concerned with critical influence factors due to dependencies such as market, institutional, and family choices for a fuel source. Biogas adoption negatively impacts the collection time and fuel-wood expenditures, but it has a positive and significant impact on crop revenues and income (GoP, 2020).

In China, all previous research studies concerning the energy sector mainly included 1) demand and supply–based energy gap, 2) energy generation sources, 3) future of the energy sector, 4) assessment of the energy sector of the country, and 5) energy mix. Regardless of the previous researcher's long-standing interest, all these studies have specific gaps, i.e., 1) there is a need to find out significant barriers and reasons compelling farmers to desolate the use of biogas technology; 2) the lack of technical barrier analysis and critical social factors on adopting biogas-installed plants discourage the investors and all types of investment; 3) financial planning for realizing economic benefits of biogas-installed plants to the farmers and investigating the critical factors due to which the farmers left biogas technology; 4) making the effective and efficient performance of biogas plants by highlighting and removing the installing and operating barriers of biogas plants in China. For contributing to the existing research gaps, the current study will address the following research questions: 1) investigate the main barriers and critical factors of biogas-installed plants for the sustainable development of biogas technology in China; 2) highlight the installing and operating barriers for removing these barriers to attract biogas plant investors for sustainable development of biogas energy and empirically evaluating the moderating role of awareness and understanding of the adopting biogas technology for sustainable improvement. The results of this research study will support government institutions, competent authorities, and NGOs to condense the weak process. The purpose of biogas plants is to produce low-cost RE to reduce greenhouse gas emissions through biogas and adequate waste management for the farmers of rural areas. Furthermore, the purposes of the present study are to provide awareness to the farmers for biogas plant adoption, build-up skills, and upgrading installation due to low capital investment and long-term benefits. The current study aimed to reduce financial risks, minimize the farmer's biogas plant investment barriers, create costless energy production through small-scale biogas plants for the farmer's self-consumption, and increase the biogas plant competencies. Additionally, ensuring the biogas industry coordination among knowledge centers, government institutions, and municipalities is the purpose of the present study. Hence, the primary purpose of conducting this study was to explore and discuss the major factors that encumber farmers from adopting the biogas technology. The further objective of this study was to attract investors to invest in biogas plants for the sustainable development of biogas energy by releasing biogas potential in China. As a step further, this study aimed to investigate the critical factors of biogas-installed plants for the sustainable development of biogas technology in China. The next section discusses the literature review then the research methodology with research design and formulation of hypotheses and describes the literature review and conceptual model. The data analysis and results section describes the testing of hypotheses. The discussion section explains the findings, implications, and conclusion, including the important limitations to the study.

LITERATURE REVIEW

Energy generation from fossil fuels is a worldwide issue. Current lifestyle and economic growth are impossible without a continued energy supply worldwide. Consistent availability of energy is highly required for modern life. The nation's economic growth and success greatly depend on the proper use of energy resources. Energy plays a fundamental role in improving the standard of living and economic development of any country or nation (Callegari et al., 2020). Energy worked as a vital building block for developing countries' economic and social development (Carmona et al., 2021). It saves an average of USD 214,406 (PRs, 37.925) million per month in different terms such as liquefied petroleum gas, wood, kerosene oil, and bio fertilizer (Arshad et al., 2018). The current most promising emerging biogas technologies in terms of their potential uses, environmental benefits, and public acceptance give a picture of the current conditions on the adoption of a biogas road map in the various EU Member States with an analysis of the status and gaps in the implementation of incentive and support policy, a discussion of non-technological barriers, and a summary of proposed solutions to increase the use of biogas energy (Capodaglio A et al., 2016). Biogas is a low-cost energy source critical for any country's sustainable development. But at present, energy generation is a challenging job using modern technology. The increasing population and current economic development are the reasons for the country's extreme demand for energy. 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 to human health, water resources, agricultural productivity, and environmental activities (Amir et al., 2019).

Many research studies have discussed that biogas provides energy to specific rural areas and fills the different types of the gap, such as reducing poverty, creating local jobs, and improving health for economic growth. Biogas production provides several environmental benefits such as power generation and 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. Hence, women of rural areas tolerate the burden of burning and woodcutting for cooking and heating. Biogas production and bio-slurry collection were effectively supported by biogas for soil fertility. Developing countries are facing a severe economic burden in importing gas and oil. Conversely, biogas adoption is financially feasible and environmentally friendly. Most portion of the power is generated from fossil fuels in China. Conversely, these energy generation sources have opposing environmental impacts and are also high-priced. The government of China has decided to eliminate the major energy crisis by using alternative, clean, and cost-effective energy sources. Modern RE methods justifiably address environmental problems and provide solutions for all energy issues (Jan and Akram, 2018). The biogas policy field is fraught with incoherence and dispersion. As a result, there is a clear possibility that the responsibility for biogas policy is dispersed and does not have a clear owner among the relevant actors. The framework of biogas regulations is inconsistent and inefficient (Gustafsson and Anderberg, 2021). However, the government of China has decided to enhance the share of RE by 5% until 2030, but biomass energy plays a vital role in achieving this target. China consumes a sizeable national treasury to import gas and oil to reduce the temporary energy shortage.

The current shortfall of energy in the country can be overcome by the effective and efficient use of biogas as an alternative energy source. China has prodigious potential to produce energy from biogas, the sixth-largest livestock-based economy globally. China meets 28.12% of its energy needs through imported gas and oil. For the last 2 decades, private contractors have installed biogas plants, international non-governmental organizations (INGOs), non-governmental organizations (NGOs), and the government sector. China has a huge animal-based population and production of biogas potential by using animal dung. In light of the findings, the system drivers can be classified into four categories according to their interrelationships. These categories are proactive answers to challenges, policy support, cooperative efforts, and technology capabilities. A recent study conducted a comprehensive literature review of seven established biogas markets, including Austria, France, Germany, Italy, Sweden, the Czech Republic, and the United Kingdom. The purpose of the study was to assist policymakers and practitioners who want to begin using biogas technology or expand their current use of it (Nevzorova and Karakaya, 2020). The biogas plant is economical due to its installation cost and also beneficial in minimizing eye and respiratory contaminations.

Biogas provides practically 14% of primary energy because it is the fourth most important energy source worldwide (Abbas et al., 2017). Many countries worldwide, including low-middle income countries, have invested in renewable energy technologies such as solar thermal, biomass, and hydro to generate reliable, indigenous, and affordable energy (Marion et al., 2017). Policies and policy instruments about biogas that are successful in one nation may not necessarily result in the same outcome in another nation because they are dependent on the larger context and the policy and economic framework (Gustafsson and Anderberg, 2022). Social reputation and time-saving attributes are also considered motivational factors and account for 33.5% each. Technology progress in low-middle income countries with social acceptance is highly linked. The primary reason for installing and constructing biogas plants in China is the inspiration of energy, saving time, and subsidy. The 42.5% of key motivational and subsidy factors included support, tax, and finance for cleaner fuel adoption (Capodaglio A. G et al., 2016; Puzzolo et al., 2016). The adoption of biogas technology provides health advantages and financial benefits with the lowest cost at 13.7%, but it depends on the awareness level of adopters (Capodaglio and Callegari, 2016; Pilloni et al., 2020). Biogas generation through organic waste has been acknowledged as a sustainable energy source (Afridi et al., 2019). On the contrary, biogas plants are successful, running with a higher number in South Asian countries such as China, Bangladesh, India, and Nepal (Wang Z et al., 2020).

THEORETICAL BACKGROUND AND FORMULATION OF HYPOTHESES

Availability of Technicians for Biogas Plants

To overcome the blamed economic conditions due to energy inefficiencies, biogas technology establishes dominance over energy decisions in rural areas in China. The supremacy is necessary to analyze the durables prevailing in energy efficiencies and the implications of biogas technologies with durable investments. The country requires experienced technicians for biogas plants. The government has rich biogas resources, including agricultural residues, fuel wood, municipal solid waste, and animal dung. Due to being an agricultural country, China has a considerable quantity of animal-based biogas resources. The functional implementation of these biogas resources can return fruitful outcome to rural areas. The proper use of manure and straw biogas resources can play a vital role in reducing emissions and increasing economic advantages (Nevzorova and Kutcherov, 2019). Small-scale anaerobic digestion, often known as SSAD, applies to the agricultural sector in Europe. The size and productivity of individual farms, on average, are insufficient to supply the feedstock requirements of medium- and large-scale operations. Even though there is clear evidence that SSAD is beneficial, the technology is still not utilized to its full potential. Most of the research conducted in the past has been on the study of large-scale systems. The current state of the SSAD technology in Europe includes identifying the process design, operational features, and influential EU policies. The most recent advances connected SSAD and the challenges met (O'Connor et al., 2021). Since incentives are structured right now, the energy goals set by the EU at the local level are impossible to achieve. To accomplish this goal, the policy mix of the EU will need to be rethought to take into account regional disparities. Even though there are certain compromises to be made in terms of socioeconomic and environmental factors, the generation of energy through agriculture can stabilize farmers' income and maintain the viability of rural communities (O'Connor et al., 2021). The biogas plants produce electricity, reduce emissions, and increase economic development by increasing profit, and their upgrading can increase environmental performance (Iqbal et al., 2018). Its parallel situation positively depicts the biogas adoption of sites and projections to increase economic growth. We formulated the first hypothesis in light of these findings as follows:

Hypothesis 1. (H1): there is a positive association between the availability of technicians for biogas plants and the adoption of biogas social projects in China.

Low-Cost and Clear Policy

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 (Capodaglio and Dondi, 2016; Wang Z et al., 2020). The prosperity of the rural areas is correlated with the adoption of biogas plants. Prosperity and biogas development include 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 (Iqbal et al., 2018). The influence of the production of biogas and the generation of energy in rural and urban areas, as well as the assistance it provides for implementing Brazilian environmental and social policies (Freitas et al., 2019). These findings are consistent with the development of biogas plants initiated in China. This importance elaborates on the significance of biogas for individual investment and its association with economic prosperity. 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, economic, and environmental benefits (Zemo et al., 2019). Overall, the conceptual model of this study is helpful to solar biogas plant issues and for the prosperity of rural people in China. These arguments lead us to the formulation of the second hypothesis as follows:

Hypothesis 2. (H2): there is a positive association between China's low-cost and clear policy to adopt biogas plants.

User Satisfaction and Biogas Plant Quality

Recently, electricity has been produced with the use of biogas. The feedstock material is a sustainable source of RE (Luyer et al., 2021). Experiments with the production of biogas and biomethane on a big scale across European nations' policy tools, agricultural intensification, and supply chain dangers are all factors that come into play while figuring out the future course of policy for particularly important countries (Zhu et al., 2019). The use of biogas potential to produce electricity can mitigate power crises, be helpful for feedstock material management, and solve the environmental issues in China. Feedstock materials such as plant, agricultural, and food waste are the best energy sources and essential components for a sustainable transition. It helps raise people's livelihood but could also denote positive impacts on their lives. The biogas potential of China is required for the appropriate use of the country's economic development. The biogas support program (BSP) is needed to be spread in rural areas all over the country (Jan and 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. According to benefit-cost analysis, using rice husk to install a biogas plant with poultry waste is feasible in China. We proposed the third hypothesis by keeping in view these findings as follows:

Hypothesis 3. (H3): there is a positive association between user satisfaction and plant quality and the adoption of biogas in China.

Operational and Maintenance Government Support and Adoption of Biogas Plants

The biogas sector of China has enormous potential and needs appropriate utilization with relevant information to the local farmers. 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 China. Operational and maintenance costs vary from installation scales. The adopted biogas plant's technical and operational design 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 show 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 affects evaluation outcomes. 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 China, the biogas power plant can be benefited from the economic conditions. These conditions are potential impacts of some elements of operation and maintenance and close associations of improvement toward biogas power projects. In the light of these arguments, we proposed the following hypothesis as follows:

Hypothesis 4. (H4): there is a positive association between operational and maintenance government support and adopting biogas in China.

Moderating Role of Awareness and Understanding Between the Availability of Technicians and Biogas Plants

Awareness and understanding of biogas technology to the farmers of the rural regions are associated with positive and significant feedback toward the economy. 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 China, 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 2 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 failed to maintain biogas production (Tumusiime et al., 2019). The current position states the evaluation is based on awareness and understanding of biogas plants, 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 farmers' intentions are affected by personal criteria to adopt biogas technology in China (Wang Z et al., 2020). In light of these arguments, we proposed the following hypotheses as follows:

Hypothesis 5. (H5): the project's awareness and understanding positively moderate the association between the availability of technicians and the adoption of biogas in China.

Hypothesis 6. (H6): the project's awareness and understanding positively moderate the association operation and maintenance of government support and adoption of biogas in China.

Hypothesis 7. (H7): the project's awareness and understanding positively moderate the association between the low-cost and clear policy and the adoption of biogas in China.

Hypothesis 8. (H8): the project's awareness and understanding positively moderate the association between user satisfaction and plant quality and adoption of biogas in China.

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 the gas connection availability, an investigation will be conducted where it has the potential to choose between connecting with a Sui gas national or biogas from agriculture waste or other alternative energies. The energy ladder model defined that any household can choose a specific fuel. Different types of fuels can be changed with this linear process. Traditional fuels like dung cake, shrubs, and firewood are used on the bottom level in China. Still, modern fuels such as electric stoves and methane gas depend on the household's average income. This model explicitly highlights the individual pay for the explained energy choice (Gautam et al., 2020). Countries worldwide face challenges by using conventional energy sources to meet their people's clean energy demands and exploring new RE sources. This theory has two main factors: economic and wealth status (Ozoh et al., 2018). In China, this study was conducted based on the theoretical background to determine the adopting factors for biogas energy plants. The assumed environmental, social, and technical factors could not be excluded from the failure or success of the biogas energy plants through consumers or society. The reflection of consumer perception can deliver through the conceptual model shown in **Figure 1** to the choice of energy source for living. The conceptual model shows the expected relationship between the independent variables (IVs) and dependent variables (DVs). The current model also shows the expected moderation between the IV and DV.

RESEARCH METHODOLOGY

This research has used non-probability (snowball) sampling questionnaires and mobile applications to improve existing biogas plants and check the potential of biogas in China. This sampling technique has not provided an equal chance for all the population members to participate in the research study. This sampling technique is used for specific population characteristics and to conduct pilot studies, qualitative research, or exploratory research. The common non-probability sampling techniques include quota sampling, snowball sampling, purposive sampling, voluntary response sampling, and convenience sampling. Working biogas plants were selected for 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 China, it was a high risk of approaching relevant respondents (the biogas plant owners).

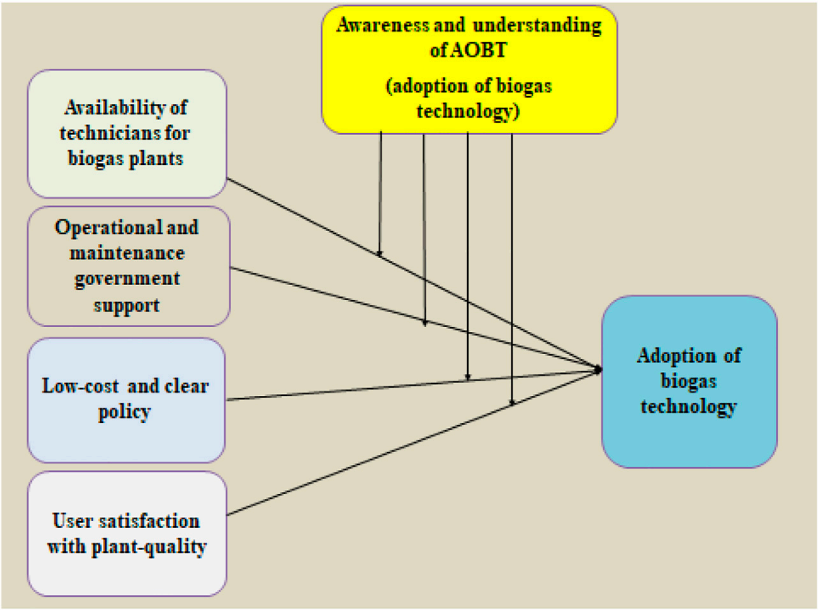

FIGURE 1 | Conceptual model.

Moreover, all representatives have a heterogeneous background in biogas plants and demographic measures (see **Supplementary Appendix Tables A1, A2**). Furthermore, snowball sampling was employed to select respondents (biogas plant owners) with diverse behaviors. Snowball sampling is unsuitable for theoretical generalization, primarily when randomization cannot be performed but a participant is referred to another participant (Ozoh et al., 2018). 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. The moderating role of awareness and understanding in adopting biogas plants is among the nexus of satisfaction and reduces the barriers. The present study has adopted the quantitative approach of data collection and the questionnaires to collect the data from the respondents.

Our research employed structural equation modeling (SEM) 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 (Urbach and Ahlemann, 2010). The extensive use of PLS-SEM in subsequent studies is evidence of its appropriateness (Ying et al., 2020). It is a component-focused strategy used to assess the relationship characteristics of the research (Urbach and Ahlemann, 2010; Ahmad et al., 2021). PLS-SEM was selected over all other covariance-based methods because it enables researchers to assess both computations and factor structures. PLS-SEM's robustness and usefulness in the researched domain have been shown by its expanding application. PLS-SEM was chosen by the authors due to its popularity and suitability, as proven by the following research (Hair et al., 2019b; Raza et al., 2020). In addition, the statistical power of partial least square route modeling is greater than that of covariance-based structural equation modeling. This shows that PLS-SEM is more useful for detecting links between the variables under study.

On the other hand, an appropriate statistical process 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 et al., 2010). 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 using measurement analysis. Reliability and validity tests or the assessment of the inner model is included in the measurement assessment model. Hypothesis/relationship testing or the evaluation of the outer model is included in the structural assessment model. The present research used PLS 3.0 software for primary data analysis and examined the links among the variables under study. Additionally, partial least square path modeling has higher statistical power than covariance-based structural equation modeling. PLS-SEM is more advantageous for intercepting relationships among the variables.

In addition, the smart-PLS for VB-SEM uses the PLS-SEM path modeling method to examine the nexus among the variables (Solangi et al., 2019). The purpose of smart-PLS is hypothesis testing, and the complex model research has adapted to it. The smart-PLS have two approaches: measurement assessment and structural models 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 was examined using Cronbach's alpha, composite reliability, and items loading. However, the discriminant validity is associated with the correlation among variables examined using Fornell-Larcker criteria, cross-loading, and heterotrait–monotrait ratio. Moreover, 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.

Sample and Procedure

This study was conducted based on presently working biogas plants. We contacted 79 biogas plant users from 35 villages, of which 63 agreed to participate in the survey. The data collection process started with a few numbers of biogas plants. After that, it increased progressively. After getting the consent of biogas plant owners, the researchers provided opened and closed-hand questionnaires using a smartphone to each biogas plant owner *via* LinkedIn and WhatsApp. This research questionnaire was applied after initial site visits, interviewing biogas plant owners, considering the existing literature, and discussing with an expert. Last, 56 filled questionnaires were returned from the total sample size of the questionnaire survey. However, the researchers discarded five questionnaires due to unmatched and inadequate responses. There were a few participants in this study; hence, the snowball sampling technique was used. This process led the researcher to attend to the still undiscovered respondents. Finally, the sample resulted in 51 usable responses from the overall sample size, and the response rate was 80.95%. The finding is generated based on a fair sample representation, and PLS-smart was used for data analysis.

The demographic features of the respondents include gender, age, and owner's experience, the owner's education, and the biogas plant names currently working. The respondents were given the proper response (see **Table 1**). The present research followed the standard 5-category scale in which one always symbolizes and five expresses as never. The questionnaire covers the personal detail of biogas plant owners and features of biogas plants, like quality, user satisfaction, biogas plant cost, and energy supply. The present study adopted six predictors of availability of technicians for biogas plants (AT) with six items, the operational and maintenance government support (OMGS) with five items, the user satisfaction and plant quality (USPQ) with five items, the low-cost and clear policy (LCCP) with seven items, adoption of biogas technology (ABT) as a dependent variable with eight items and finally awareness, and understanding of the adoption of biogas technology (AUAOBT) as a moderator variable with six items. The data analysis and results section tables show these variables with links. 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 with three questions and tested before the author's application; some questions covered the satisfaction of biogas plant users. Some online questions are related to the investment in biogas plants and the most favorable scenario for the satisfaction of biogas plant users. Some online questions are asked from the owners of biogas plants with enough knowledge about biogas plants' operation. These questions include the operational and maintenance cost of biogas plants and day-to-day plant expenses. Finally, some questions are related to the technical and skilled laborers and trained owners of biogas plants.

Instrument and Variable Measurement

Researchers have adopted all items from different previous literature reports in this research. Items based on the availability of technicians for biogas plants were constructed from the study (January 2017). Things regarding the operational and maintenance of government support were adopted from the research study (Shah and Sahito, 2017). Items related to the low-cost and clear policy were assumed (Ozoh et al., 2018). Objects related to user satisfaction and plant quality were constructed (Chin and Newsted, 1999). Items that belong to the awareness and understanding of adopting biogas technology (AOBT) were adopted (Wang Z et al., 2020). Finally, items related to the adoption of biogas technology were adopted from this study (Hair et al., 2014).

DATA ANALYSIS AND RESULTS

All verified validity and reliability values in this measurement model are given below in relevant tables. The measurement assessment model shown in **Figure 2** indicates the 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 negatively affects ABT and accepts AT, AUAOBT, LCCP, and USPQ. In addition, the results also show that AUAOBT significantly moderates the links of AT, AUAOBT, LCCP, USPQ, and ABT and accepts AT, AUAOBT, LCCP, and USPQ. This section analyzes convergent validity that shows the correlation among items. The results and links reported in **Table 2** indicate 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. AVE values are also higher than 0.50, and composite reliability (C.R) values are greater than 0.70. These values have indicated a high correlation among items and valid convergent validity.

Measurement Assessment Model

The measurement model confirms the reliability and validity of the constructs, and the factor loadings of all items were approved by the model (Hair et al., 2019a). The measurement evaluation model is consistent on reliability tests (item reliability and internal consistency reliability) and validity tests (convergent validity and discriminant validity) (Hair et al., 2011). All item loadings are well upstairs with the threshold value of 0.5 (Hair et al., 2014) (**Table 2**). The study analysis verified that all 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

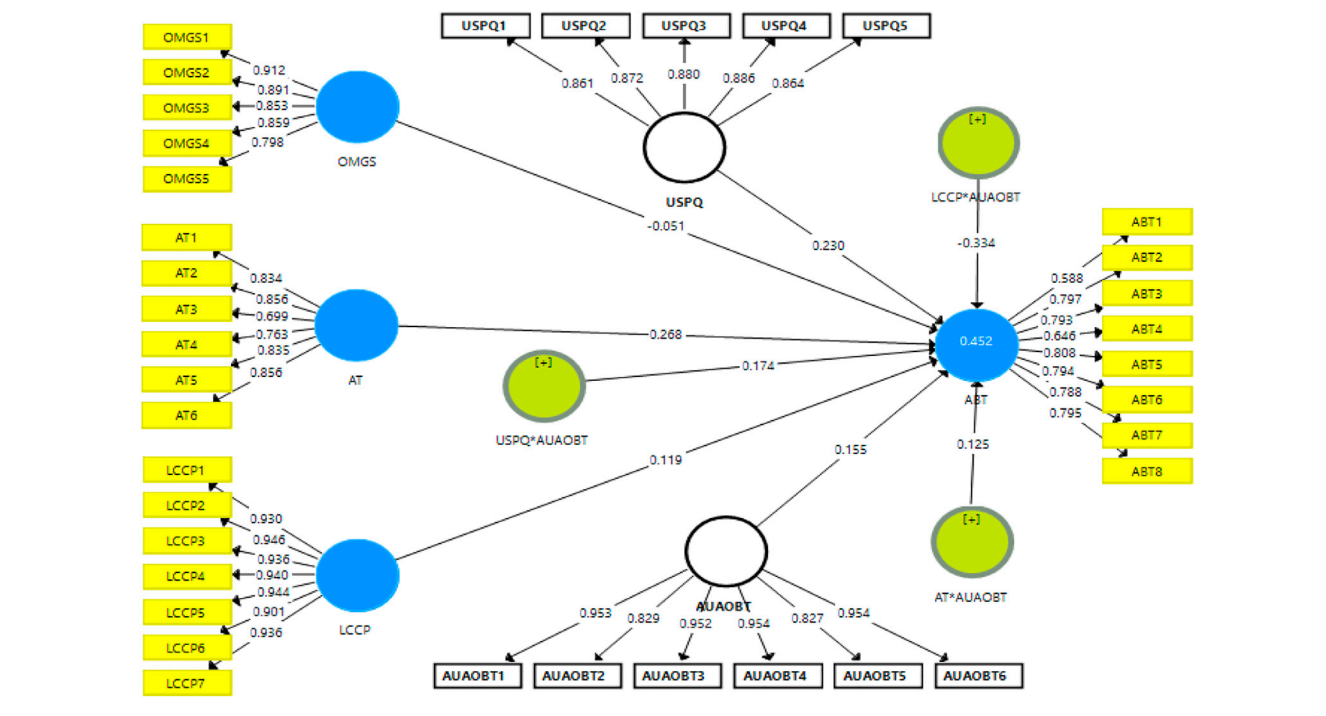

FIGURE 2 | Measurement model assessment.

reliability value for each standard exceeds the cut-off point of 0.70, indicating that the measurements are reliable (Anderson and 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), and 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.

The research findings also include the correlation assessment among variables named discriminant validity. The cross-loading was used to test the discriminant validity. These values have indicated a low correlation among variables and verify discriminant validity. The findings section also shows in **Table 3** the discriminant validity through the Fornell–Larcker criterion about the nexus among the variables. The bold values in **Table 4** show that the factors have a strong relationship, while others have weak ones. The bold values of the cross-loadings are compared with other factors row-wise to check discriminant validity. The variable values 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. The measurement assessment model is shown in **Figure 2**, indicating the variables' factor loading. 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 heterotrait–monotrait ratio of correlations (HTMT) for the discriminant validity measure is considered more suitable due to different researchers' criticism of 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 (Ali et al., 2021). All values are less than 0.90, as shown in **Table 5**. The findings section has also shown the variables' discriminant validity. The variable values have shown that the values indicated the nexus with the variable itself are higher than those with other variables. This research also used the HTMT ratio to examine the correlation among variables. The statistics of HTMT have shown that the values are less than 0.85.

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 plant 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, ($\beta = 0.155$; $t = 1.874 > 1.64$;

TABLE 2 | Convergent validity analysis.

Item	Loading	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			

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.
Bold values show that the factors have a strong relationship.

TABLE 3 | Fornell–Larcker criterion.

Variable	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 4 | Cross-loading.

Item	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**

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 | Discriminant validity using the heterotrait–monotrait ratio (HTMT).

Variable	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.

TABLE 6 | Structural model results (hypothesis testing).

Hypothesis	Relationship	Beta	S.D.	T-statistics	*p*-value	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 1: 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 the biogas technology.
Notes 2: (*), the moderating relationship indicated by the asterisk among the variables.

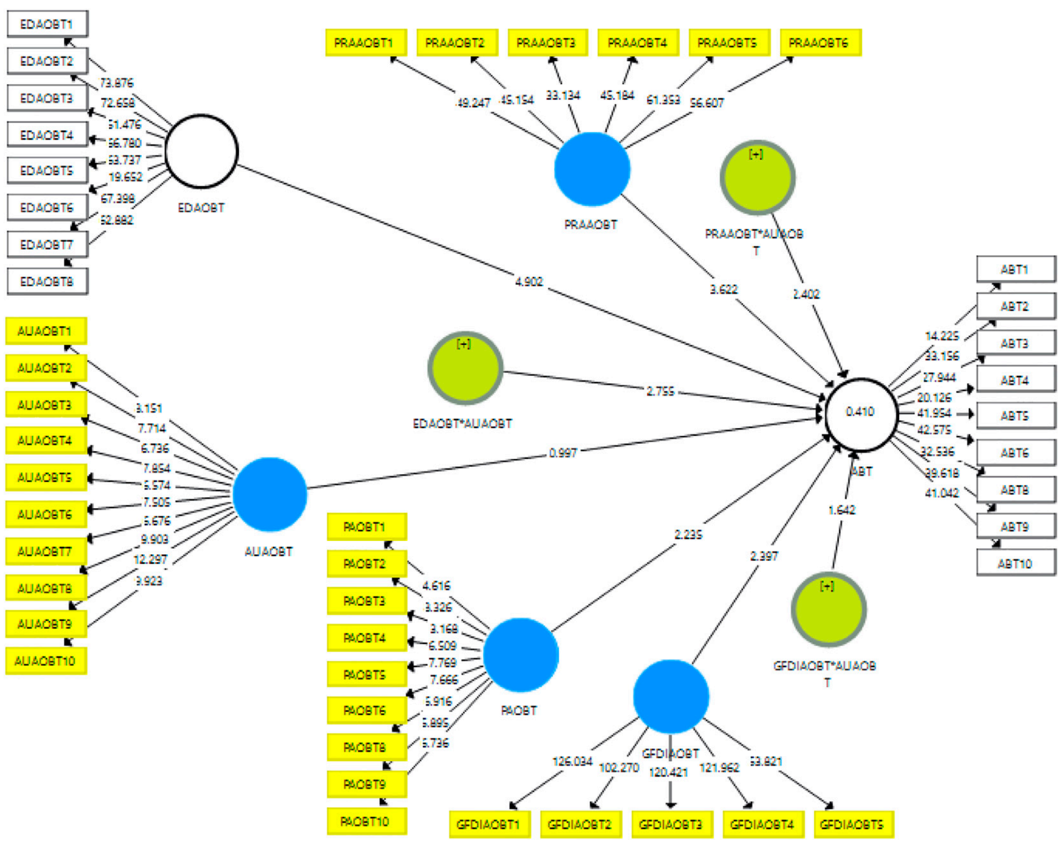

FIGURE 3 | Structural model assessment.

$p < 0.05$), low-cost and clear policy relationship (moderator), (β = 0.334; t = 5.077 > 1.64; $p < 0.05$), user satisfaction and plant-quality, (β = 0.119; t = 1.695 > 1.64; $p < 0.05$), user satisfaction and plant-quality relationship (moderator), (β = 0.174; t = 3.125 > 1.64; $p < 0.05$), and operational and maintenance government support (β = –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 China. 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 more 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

TABLE 7 | Satisfaction and views of biogas plant users.

Description	Case (%)	Response (%)	Frequency
Food is cleaner and tastier using 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 and 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 the environment	8.9	4.3	5
Reputation in the society	10.9	6.4	6
Others	12.9	7.4	7

TABLE 8 | Barriers and challenging factors.

Variable	Description	Case (%)	Response (%)	Frequency
Reasons through which users are not fully satisfied with biogas plants	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 plants	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 using 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 for a biogas plant work failure	Poor material applied for construction	9.5	7.5	18.5
	Poor installation service quality	5	3.4	8.7
	Old/outdated design	10	7.6	18.7
	Bio-slurry mismanagement	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 plants	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 the pipeline	11	8.4	20.7
	Blockage of the pipeline caused by condensed water	10	7.7	18.7
	Others	16	16.9	30.5

performance through SHS. These are the typical values of f^2, including 0.02, 0.15, and 0.35, which indicate small, medium, and large effects in three categories, respectively. Thus, the value of f^2 assumed that the effect size differs from medium to large (see **Table 6**). **Table 6** has several kinds of statistical techniques. The structural assessment model is shown 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 adopting biogas technology in China.

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 China. 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 China. Second, to explore the actual issues of biogas plant owners and collect practical experience knowledge about the maintenance and operations hindrances, we conducted semi-structured interviews about various operational aspects of biogas plants with illiterate (those who cannot fill the questionnaires) biogas plant owners. The aspects include maintenance and operation costs of biogas plants, availability of technicians, cost of capital, initial installing cost, and technology awareness. We have 43 biogas plant owners interviewed from rural areas of China. Finally, all the parameters considered for biogas plants and the response of biogas plant owners are revealed in **Tables 7**, **8** and are shown in (%). All % figures are the division of responses collected from (illiterate) biogas plant owners. **Table 7** demonstrates the satisfaction and views of respondents (biogas plant owners) from China for their biogas plants. The primary reasons are the easy operation of the biogas plant, availability of technicians, economic advantages, sufficient gas collection for food preparation, gas used for lighting, and social reputation. Countries such as India, Nepal, and Bangladesh generally have technical service availability as a sufficient driving force for social project development (Breitenmoser et al., 2019). A total of 64% of respondents said that adopting biogas technology needed user satisfaction with a biogas plant in China. About 21% of respondents expressed that a lower cost and straightforward policy are required for biogas technology, but 15% disclosed that user satisfaction and plant quality are also necessary. Additionally, half of the biogas plant user respondents reported that their plants are functional and serviceable.

Important Barriers and Inspiring Factors

The partial adoption of biogas plants is facing a list of various discouraging factors. Unavailability of technicians has the highest response attributed to 16.8%, whereas frequent operational problems were 13%, and low biogas pressure is another problem. Many operational problems are faced by the biogas plants, such as deterioration of the steel parts, roof and wall crack development of the biogas plants, and leakages of the gas pressure (Zemo et al., 2019; Scheutz and Fredenslund, 2019). The lowest pressure recorded for biogas was 4.9%, a severe issue for properly cooking food. Poor mixing in feed is the main reason for the low pressure or biogas inside the reactor. The proper stirring mechanism in biogas plants is required to improve the gas pressure for the end-user (Nsair et al., 2019). The frequent technical problems are the reasons for the delay in 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 was equal to zero for biogas consumers. The users of biogas plants feel failure and discouragement due to the contribution of these factors, and the weak approval of technicians is attributed to the policy framework of the project. The sustainability of a biogas plant project is negatively affected without a supporting system and technical assistance running in the background (Pandyaswargo et al., 2019). Barriers and challenges of currently working biogas plants in China are shown in **Table 8**.

DISCUSSION AND IMPLICATIONS

The present research has both theoretical and empirical implications. The current significant literary work contributes to the biotechnology and socioeconomic literature. This study presents the influence of four factors such as AT, OMGS, LCCP, USPQ, AUAOBT, and ABT, to attract the farmers to biogas plant adoption and sustainable development of biogas technology in China. The study provides guidelines to the policymakers and higher management of the government sector and private NGOs to facilitate farmers adopting biogas plants and improving biogas technology. The present study conveys extreme importance for policymakers, economists, and competent energy sector authorities to remove the major barriers and provide financial assistance to the farmers for adopting biogas technology plants. The best planning of the top management can reduce critical factors and barriers to biogas plants, contributing to biogas-related awareness and understanding. Therefore, biogas technology adoption can reduce the energy crisis and improve the financial position of the farmers. Still, government support can enhance the biogas plant adoption and motivational level among the rural areas and new investors.

The results indicate that the low-cost and clear policy significantly relates to adopting biogas plants and attracting new investors due to expenditure saving and mechanism satisfaction. The low-cost and clear biogas technology policy increases farmers' confidence in adopting biogas plants and provides better living standards for rural areas. A past study has supported these results (Garfí et al., 2019). This study also discussed that awareness and maintenance of biogas plants is not a perfect moderator between operating and upkeep of biogas plants and adopting biogas technology. The study reveals that awareness and understanding of biogas plants affect the adoption capacity of biogas technology in rural areas of China. The current results agree with Luo et al. (2021). The past studies indicate that awareness and understanding of biogas plants affect installation factors and adoption of biogas technology. This study has also noted that awareness and understanding of biogas plants is a considerable moderator between low-cost and clear policy and adoption of biogas technology in China. The results are in line with the results of the previous study (Havrysh et al., 2020), which show that the awareness and understanding of biogas technology affect the low-cost and clear policy of the government and attract the farmers of rural areas to adopt biogas plants and save money (Winquist et al., 2019).

The current study suggested that the availability of technicians proves the adoption of biogas plants and socially and economically benefits the farmers of selected rural areas. The low-cost and clear policy has a high-performance turnover to attract farmers and new investors to invest in biogas plants. The study also indicates that operational and maintenance government supports positively correlate with attracting biogas plant users and the social-economic benefit of biogas plants. User satisfaction and plant quality are a progressive way to attract farmers and new investors to adopt biogas plants and reduce the energy crisis overall and improve domestic prosperity on their own. The analysis of the study proves that user satisfaction and plant quality can play a major role in attracting local area farmers, private NGOs, and new investors to invest in biogas plants and earn economic and social benefits in China. The findings of this study offer practical guidelines for policymakers, experts, institutional bodies, regulators, the ministry of water power, and the higher management of the alternative energy development board (AEDB) to adopt these factors for a high level of former satisfaction, attracting rural farmers of selected areas for the sustainable development of biogas technology. The competent institutional authorities need to consider AT, OMGS, LCCP, and USPQ to save farmers' time, reduce cost and energy crisis, and provide better living standards for rural farmers who provide low-cost biogas energy mechanisms.

Second, the financial benefits of biogas technology are also evaluated from the interviewees' responses in this study. About 58% of respondents agree that they saved fuel expenditure, whereas 42% of respondents (biogas plant owners) did not agree. Recent studies have 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. In comparison, 53% of respondents had no change in their financial situation. So here this change is a feature of the number of family members and their expenditures. Joint families save less, while nuclear families are kept more in rural China and supported by contributing equally. About 53% of families could not hold their money due to aforementioned reasons. The present study's results match the past (Akter et al., 2021). Moreover, the current study results show that the availability of technicians for biogas plants assessing the adoption of biogas technology has a significant and positive relationship with the sustainable development of biogas plants. The present study results verify the past study results, underlining the impact of the availability of technicians for biogas plants on farmers adopting biogas technology (Mengistu et al., 2016). The current research suggests that the availability of technology for biogas plant elements helps attract the former to adopt biogas plants and assists the top management in removing the installation barriers of the biogas plant. Additionally, the study results explore that operational and maintenance government support positively affects the adoption and motivation of the farmers for biogas plants. The present study shows that operational and maintenance government support significantly impacts biogas plants and indicates social and economic benefits. These results approve the results of the past research (Wang X et al., 2020). This study implies that providing government support for operating and maintaining biogas plants improves the adoption of biogas and increases the attraction for new farmers to adopt this technology.

The fully satisfied users have significantly reduced their expenditures after installing a biogas plant. The reduction of expenses is considered a primary adaptive reason for the satisfaction of partially satisfied users at a specific point. Biogas plants can solve and improve a household's financial status, as indicated by this variable. Advantages include, from the environmental perspective, cleanliness, and safety after installing biogas plants, a substantial drop in fire accidents, and less smoke production attributed to better health and a clean kitchen. A total of 33% of respondents highlighted a significant decrease in fire accidents. Freedom from sickness was reported in 15%, which 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 health. A total of 43% did not answer the questions during interviews.

Managerial Implications

Our research findings offer valuable insights into rural people and government/NGOs working in China. The study suggests that biogas plants are very suitable for the rural areas of China to save their expenditures and make prosperous economic development. 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 adopting biogas plants has positive and significant relationships with the availability of technicians and user satisfaction with plant quality in China. 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 China INGOs/NGOs should improve the potion of subsidies for biogas plants and economic development for the home-grown farmers. Most of the problems can be solved 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 provinces rather than Beijing, Tianjin, and Hebei with the support of the government INGOs/NGOs.

CONCLUSION AND LIMITATIONS

Biogas is considered a powerful source to produce energy worldwide. The increasing rate of biogas plants is the primary issue in adopting modern biogas plants in China and other low-income countries. Although the government of China and some relevant INGO/NGOs are trying to make acceptable said technology by giving subsidies for biogas plants to home-grown farmers, the acceptance ratio is very low in rural areas and village communities. According to the choice theory of energy, the population 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 energy protection, 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.

Consequently, the present study indicates that all independent variables are significant and positively correlated with adopting biogas technology, reducing energy crises, and attaining cost-saving purposes in rural China. The current study has explored that removing the selected barriers is better and more significant for sustainable green energy generation, financial management, cost-effectiveness, return on capital investment, and assessing the fixed factors before adopting biogas plants in rural China. The outcomes of this study will also identify to the government that it is highly required to take appropriate actions to spread information and awareness on adopting biogas technology and start its development programs in the future. The value of R^2 in **Table 6** for AT is 0.478, which shows that the present conceptual model has extensive explanatory power to attract farmers to adopt biogas plants in rural China. The Q^2 value is 0.248, which indicates that the conceptual framework has significant and positive predictive relevance, which recommends that the selected barriers should be removed to increase the likelihood of adopting biogas plants in the rural areas of China. The chosen variables express their meaningful relationship to an LCCP in **Figure 1** in the model; the values of t statistic are result-oriented and more critical than 1.64, and the low-cost and clear policy positively and significantly impacts attracting farmers to adopt biogas plants in the rural area of China. In the structural assessment model, the moderated variable's importance has positive signs and indicates an exclusively substantial relationship in the structural assessment model. The present study has also displayed that selected variables and their adopted moderation in this conceptual model have a significant and positive impact on the structural assessment model on adopting biogas plants in the rural areas of China.

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 Chinese government to develop and promote biogas technology in rural areas of China. The government should be planning a clear policy for RE projects for operation and maintenance, capacity building sessions, technical support, and launching a media complaint about maintenance to develop biogas plants. The rural area of China has great potential for biogas technology to overcome domestic energy shortages. Consequently, some training steps should be taken by the relevant NGOs/INGOs and the government of China for sustainable project development, maintenance, and smooth operation of biogas plants in rural areas. Hence, government institutions of China and relevant INGO/NGOs should arrange skilled technicians' technical centers and provide the appropriate installation of biogas plants to the consumer after-sales service. In this current position, the other variables such as poverty, biogas plant owner literacy, the quantity of the animals, the required area for biogas plants, and other social and economic factors affecting the adoption of biogas plants have been entirely ignored. Hence, interested researchers must also identify the rest of the elements to adopting biogas plants while considering the results of this study. We have selected to adopt a biogas plant in the rural areas of a developing country such as China. Thus, the current study results are not equally valid for developed and underdeveloped countries. So the authors in the future must investigate the encouragement to attract the farmers to adopt biogas plants in developed countries.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**; further inquiries can be directed to the corresponding authors.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by This research study was conducted according to the Declaration of Helsinki guidelines. The Institutional Review Board of North China Electric Power University has approved the study. (protocol code 926- on 27 November 2021). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

SA: writing—original draft, formal analysis, data handling, variable construction, and methodology. QY: supervision. MI: conceptualization, software, writing review, and editing. ZC: funding acquisition, writing review, and editing. All authors have read and agreed to the published version of the manuscript.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2022.887084/full#supplementary-material

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