Research Article

Factors Affecting the Willingness to Adopt Biogas System at Small Pig Farms in Mekong Delta, Vietnam

Budi Guntoro[1*], Nguyen Hoang Qui[1,2], Ahmad Romadhoni Surya Putra[1], Nguyen Thi Anh Thu[1,2] and Nguyen Van Vui[2]

[1]*Department of Livestock Socio-Economics, Faculty of Animal Science, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia;* [2]*Department of Animal Science and Veterinary Medicine, School of Agriculture-Aquaculture, Tra Vinh University, Tra Vinh City 87000, Vietnam.*

Abstract | Applying biogas is one of the most effective methods to reduce environmental emissions in pig farming. By analyzing the extended technology acceptance model (TAM extended), this study investigated the factors of social profiles, production characteristics, and perception of farmers affecting the acceptance of biogas systems in pig farms. The data showed that occupation, perceived usefulness, information awareness, social influence, and perceived cost were significant predictors of farmers' willingness to adopt biogas. Specifically, occupation (B = -0.088, p = 0.007) and perceived usefulness also negatively affected (B = -0.149, p = 0.005) the willingness to adopt biogas; in addition, farmers having off-farm jobs or having high perceived usefulness of biogas were less likely to adopt biogas. In contrast, information awareness (B = 0.295, p < 0.001), social influence (B = 0.389, p < 0.001), and perceived cost (B = 0.246, p < 0.001) were positively correlated with biogas adoption. Other variables such as age, gender, experience, education level, production scale, and income did not significantly influence biogas adoption. The study concluded that promoting the willingness to adopt biogas in pig farms requires policy interventions focusing on raising awareness, leveraging social influence, and addressing economic factors related to investment costs and benefits.

Received | September 07, 2024; **Accepted** | October 03, 2024; **Published** | October 22, 2024
***Correspondence** | Budi Guntoro, Department of Livestock Socio-Economics, Faculty of Animal Science, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia; **Email:** budiguntoro@ugm.ac.id
Citation | Guntoro, B., N.H. Qui, A.R.S. Putra, N.T.A. Thu and N.V. Vui. 2024. Factors affecting the willingness to adopt biogas system at small pig farms in Mekong delta, Vietnam. *Pakistan Journal of Agricultural Research,* 37(4): 320-330.
DOI | https://dx.doi.org/10.17582/journal.pjar/2024/37.4.320.330
Keywords | Biogas, Extended TAM, Small pig farm, Sustainable environment

Introduction

Currently, the livestock industry is rapidly developing. Along with these developments, environmental problems caused by livestock waste have also received social attention. The primary source of ammonia (NH_3) emissions comes from the livestock industry, of which livestock accounts for large proportion. A total of 40% of methane gas generated from livestock activities has a higher global warming potential than CO_2 (Putri *et al*., 2020). In particular, large-scale pig farming is characterized by producing too much waste on a small area of land, which becomes a source of environmental pollution if not properly treated and disposed of. Therefore, changes in livestock farming practices are needed to help farmers feel secure with their farms and increase production (Busch *et al*., 2018). A practical step to reduce greenhouse gas and ammonia emissions is to use biogas production technology by fermenting animal waste (Busch *et al*., 2018).

Countries worldwide are increasingly interested in sustainable energy production technologies such as renewable energy. In Vietnam, livestock waste is a promising sustainable energy source, which can be effectively used to produce biogas energy and electricity (Noi *et al*., 2022; Roubík *et al*., 2017). In particular, pig feces is produced in large quantities. If well managed, this will reduce waste volume and create nutrient-rich residues for crops. If not properly managed, it harms the environment (Roubík *et al*., 2018). In addition, in Southeast Asian countries, biogas is applied on large farms due to low costs and usage habits (Lin *et al*., 2022). Therefore, in Vietnam, the application of biogas in livestock farming is increasingly widely applied to solve two main goals: (1) to solve problems related to the livestock environment and (2) to solve problems related to energy used for households partly (Noi *et al*., 2022).

Adapting this energy technology will take some time but will benefit humanity in the long run (Lin *et al*., 2022). However, using renewable energy, specifically biogas, on farms has many shortcomings. Factors include household income, education level of the household head, and lack of access to technical services rooted in poverty, lack of knowledge, lack of education, and financial issues. Gender also plays a role in technology adoption. Therefore, it is essential to consider farmers' willingness and ability to adopt biogas (Burg *et al*., 2021). Biogas appears to be the optimal solution to many problems in the Mekong Delta. Still, its broader use may be hindered by financial and knowledge barriers, lack of stable raw material supply, local conditions, and other issues (Truc *et al*., 2017). In addition, biogas adoption is influenced by many factors, including Perceived Innovativeness (PI), Perceived Usefulness (PU), Perceived Ease of Use (PEU), Information/Awareness (IA), Social Influence (SI), and Perceived Cost (PC). These are also proposed in the Technology Acceptance Model (TAM) proposed by (Davis, 1989). Several studies on technology adoption and information technology have concluded that TAM is valuable in predicting individuals' technology acceptance (Diaz *et al*., 2021). Along with it, demographic variables have also been included to assess the likelihood of technology adoption. Socio-demographic factors such as age, education level, and farm size of farmers influence technology adoption (Michels *et al*., 2020). Factors such as education level and farm size can also make a difference in decision between small-scale farmers and their counterparts when adopting the technology (Caffaro and Cavallo, 2019). Therefore, understanding the farmer's awareness of using the biogas system is considered a reference for model development and accelerating its adoption among farmers. In particular, the study was conducted in Ben Tre province, one of the developing pig-raising provinces in the Mekong Delta with 330.8 thousand pigs (GSO, 2021), which will contribute to finding more reasonable solutions to encourage and support farmers in the process of implementing biogas. For the above reasons, the study was conducted to assess the impact of factors on the readiness to apply biogas in pig farming.

Materials and Methods

Location

The study was conducted in Ben Tre province, Vietnam, from September to December 2023. The study selected Ben Tre province because the number of pigs raised in the province is quite large, which can represent other provinces in the Mekong Delta. In addition, Ben Tre is also located on the route connecting to Ho Chi Minh City, one of the largest markets in Southern Vietnam. Furthermore, most pig farmers in the province apply the biogas model or have contact with this model.

Theoretical framework

Several theories have been proposed to explain the intention to use or adopt a technology. For example, the TAM of (Davis, 1989) is widely used and empirically tested in studies on technology adoption. TAM is one of the most popular and accepted models in technology adoption and diffusion due to its recent empirical support (Rezaei *et al*., 2020). TAM was developed to inform technology implementers whether individuals will accept a new technology. Several studies on technology adoption and information technology have concluded that TAM is valuable in predicting individuals' technology acceptance (Diaz *et al*., 2021).

The primary constructs of TAM include PU and PEOU, as well as attitude and behavioral intention to use new technology (Davis, 1989). Researchers have extended the TAM and added some other constructs. Jeong and Yoon (2013) extended the model by adding perceived cost, perceived effectiveness, and reliability. Along with trust, social norms, and perceived risk have also been added to the new construct of TAM (Pithoon *et al.*, 2020). Therefore, adding other variables may help enhance the predictive power of TAM (Rind *et al.*, 2017). Davis (1989) defined PU as the extent to which a person believes using a particular system will enhance job performance. Since PU is one of the primary constructs of TAM, a technological innovation introduced with a higher PU rate is more likely to have a positive use-performance relationship. The PI construct identifies those farmers who are relatively early adopters of technology compared to their counterparts. It helps identify those who adopt technological improvements early (Agarwal and Prasad, 1998). Several studies have also used SI as a determinant influencing an individual to adopt or use a new technology. In the context of this study, SI is the perception that if most of the farmer's friends, relatives, and close associates use the technology, they are also influenced to use it. Referring to the farmer's knowledge about the existence of the technology, IA is also a fundamental construct included in the extended TAM. The farmer's IA can come from extension agents and various media platforms. PC is also one of the crucial constructs in expanding TAM. Most studies on technology adoption have found that PC has a negative impact on the actual use of technology (Wu and Wang, 2005). Finally, socio-demographic factors such as age, education level, and farm size of farmers influence technology adoption (Michels *et al.*, 2020). Factors such as education level and farm size can also make a difference in technology adoption between smallholder farmers and their counterparts (Caffaro and Cavallo, 2019).

In the current model of biogas adoption in smallholders, the study hypothesized that farmers' willingness to adopt biogas application is determined by PU, PEOU, PI, SI, IA, and PC, and socio-demographic factors influence farmers' perceptions. Other factors were excluded from this study. The conceptual framework of the study is performed in Figure 1.

Data collection

This study collected data from pig farming households with at least five years of experience and a farming scale of at least ten pigs to ensure reliability and understanding of farmers' livestock farming. A random sampling method was applied to select pig farming households in Ben Tre province, with 210 chosen households (70 farmers per district) to participate in the study. This sample size meets the minimum requirements for data analysis according to previous studies, ensuring reliability and the ability to generalize the research results. According to the recommendation of Levine and Stephan (2010), a research sample of at least 30 subjects in each area is considered sufficient for statistical analysis. The study used a multiple-choice questionnaire designed in Vietnamese and then translated into English to serve the data collection and analysis process (Qui *et al.*, 2020, 2021). The data collection process was divided into two main parts:

Part 1: Collecting sociological information and pig production on farms. Including factors such as age, gender, occupation, farming system, experience, education, labor, income, purpose of farming, and training. This part aims to understand better the social and production context of farmers in the study.

Part 2: Collect data on the awareness and attitudes of the farmers towards biogas application based on the extended TAM. The variables in this part include PI, PU, PEU, IA, SI, PC, and the willingness to adopt a biogas system at their farm. Farmers were asked to rate their level of agreement with statements about the benefits and difficulties of using biogas on a scale of 1 to 5, from completely disagree to completely agree.

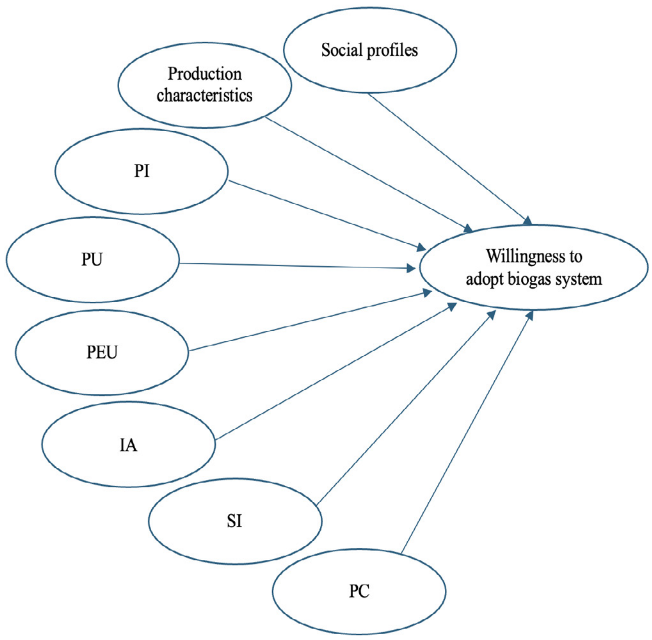

Figure 1: *The conceptual framework of the biogas acceptance model.*

Table 1: *The definitions of variables used in the study.*

Age	The age of farmers refers to those who directly work at pig farms and use and connect with biogas systems. The age variable is assessed through 3 types: 1 is <40 years old, 2 is 40-60 years old, and 3 is >60 years.
Gender	The gender of farmers refers to the role of farmers in the family and is coded in binary form with values of 1 for males and 0 for females.
Occupation	The main occupation of farmers can include jobs such as pig farming or other jobs outside the agricultural sector. This variable helps determine the farmer's concentration level on pig farming activities. Divided into 1 is pig production, 2 is pig and other animal production, and 3 is other jobs
Farming system	The type of livestock farming system that the farmer applies can be traditional farming or a mixed model including 1 for integrated farming (pig and plant) and 2 for VAC integrated farming (VAC is the integrated farming including fish, horticulture, and animal farm in Vietnam)
Experience	The number of years that the farmers have been involved in pig farming, representing the knowledge and skills that the farmer has accumulated during the farming process, including 1 is <5 years, 2 is 5-10 years, 3 is 11-20 years and 4 is >20 years
Education	The level of formal education that the farmer has achieved is coded in terms of education level, such as 1 being primary school, 2 being secondary school, and 3 being high school.
Labor	The number of family or farm workers involved in pig farming. This variable represents the scale of human resources supporting livestock farming, including 1 is <3 people, 2 is 3-4 people, and 3 is >4 people
Income	Total income of farmers or from livestock farming activities, calculated by month, representing the economic level of the livestock farming, including 1 is <99$, 2 is 100-200$, 3 is >200$.
Purpose of farming	The purpose for which farmers raise pigs includes 1 for sow raising, 2 for finisher raising, 3 for piglet raising, and 4 for growing all types of pigs. This variable helps to determine the ultimate goal of livestock farming.
Training	The extent or frequency with which farmers have participated in training courses related to livestock farming or biogas technology. This variable represents farmers' access to and understanding of the biogas system, including 1 for participating and 0 for not participating.
TAM expanded variables	According to the extended TAM theory, the variables in the perception of pig farmers using biogas include PI, PU, PEU, IA, SI, PC, and willingness to adopt biogas. These variables are rated from low to high levels with 1 to 5 used, with 1 corresponding to very low and increasing to 5 corresponding to very high.

The variables used in the study are defined in Table 1.

Data analysis

Data were analyzed by descriptive and multiple logistic regression (MLR) methods using SPSS version 26.0 (IBM SPSS, Armonk, NY, USA). For the proposed hypothesis, the analysis method was used to assess farmers' awareness of the possibility of applying the biogas model. Specifically, we applied the extended TAM method. We used three questions to determine PI, four questions to assess PU, four questions to assess PEU, three questions to assess IA, three questions to assess SI, and three questions to determine PC to record the awareness information of pig farmers about biogas. We also used three questions to determine willingness to adopt biogas. The scores were evaluated from 1 to 5, respectively. All indicators were assessed according to the average score of the questions posed. Cronbach's alpha of the scale is 0.948, indicating high reliability. In the present study, the dependent variable (Y) is the willingness of pig farmers to apply biogas at the farm, which is calculated and used as a continuous variable. The independent variables X_n include sociological variables: X_1 age, X_2 gender, X_3 occupation, X_4 farming purpose, X_5 experience, X_6 education level, X_7 number of pigs, X_8 labor, X_9 income, X_{10} farming purpose, X_{11} biogas training. Variables on PI awareness: PU, PEU, IA, SI, PC. From the above variables, we can establish a specific formula as follows:

$$Y_e = b_0 + b_1X_1 + b_2X_2 + \ldots + b_{11}X_{11}$$

In which: Y is the probability of willingness to adopt biogas for pig farmers at their farm. X_1 to X_{11} are the independent variables, as mentioned above. b is the regression coefficient.

Multivariate logistic regression (MLR) analysis in this study explored the impact of independent variables, including age, gender, occupation, model, experience, education level, number of pigs, labor, income, raising purpose, training on biogas, cognitive variables including PI, PU, PEU, IA, SI, PC on the dependent variable which is the willingness of pig farmers to apply biogas at the farm. The expected results show that an increase or decrease in one of the independent variables will lead to an increase or decrease in the willingness of pig farmers to apply biogas at the farm.

Results and Discussion

Table 2 illustrate a well-established, small-size pig farming characterized by experienced farmers increasingly adopting integrated and sustainable farming practices. The data show a detailed profile of pig farmers, mainly composed of farmers aged 40–60 (64.8%), with the majority being male (63.8%). Farmers in the survey area are experienced, with 78.6% of respondents having 11–20 years. Education levels indicate that most have completed secondary school (60.5%), with 3–4 workers (56.7%) typically employed on the farm. Occupational focus is evenly divided between those engaged solely in pig farming (51.0%) and those combining pig farming with other animals (49.0%). Integrated farming systems, particularly those combining pig production and crop production, dominated the interview group (86.2%), reflecting the widespread adoption of sustainable agricultural practices. Income showed that more than half of farmers earned between $100-200 per month. Farms were multi-output, with 77.6% of farmers raising all sows, finishers, and piglets. Notably, 71.4% of farmers had received training, particularly in biogas production, indicating a significant commitment to environmentally sustainable practices. Production characteristics highlighted a farming scale of 50-100 pigs (47.1%) and an average number of sows and finishers of 8.11 and 40.31, respectively.

Table 3 provides a comprehensive view of farmers awareness and attitudes towards using biogas in livestock farming. Farmers showed a relatively high level of PI. Notably, 57.6% of the respondents said they would seek to apply innovations in livestock farming, and 63.8% admitted that they were regular testers of innovations. The PU was highly recorded in the study. Notably, 50.5% of farmers believed that biogas would reduce environmental pollution, and 77.6% agreed it would save time and costs for waste treatment. In addition, most farmers (72.4%) believed biogas could be used for heating, cooking, or generating electricity for the household. The PEOU of biogas was also highly rated, with an average score of 4.041. Most farmers (82.9%) believed biogas could be applied to small farms, and 73.3% thought they could quickly learn how to install and operate a biogas system. The level of IA about biogas had an average score of 3.960. 77.1% of the respondents reported that other households were using biogas, and 71.9% of the farmers reported that they had relatives using biogas on their farms. SI was highly rated, with 77.1% of respondents believing other households were using biogas, and 54.3% were encouraged by agricultural

Table 2: *Social and production characteristics of pig farming households.*

Variables	Categories	Results	
		N	Percentage
Social profiles			
Age	<40 years old	19	9.0
	40-60 years old	136	64.8
	>60 years	55	26.2
Gender	Female	76	36.2
	Male	134	63.8
Occupation	Pig production	107	51.0
	Pig and other animal's production	103	49.0
	Other jobs	21	10.0
Farming system	Integrated farming (pig and plant)	181	86.2
	Integrated farming (VAC)	8	3.8
Experience	<5 years	9	4.3
	5-10 years	11	5.2
	11-20 years	165	78.6
	>20 years	25	11.9
Education	Primary school	14	6.7
	Secondary school	127	60.5
	High school	69	32.9
Labor	<3 people	82	39.0
	3-4 people	119	56.7
	>4 people	9	4.3
Income	<99$	27	12.9
	100-200$	116	55.2
	>200$	67	31.9
Purpose	Sow raising	19	9.0
	Finisher raising	25	11.9
	Piglet raising	3	1.4
	All types of pigs	163	77.6
Training	No training	60	28.6
	Training for biogas	150	71.4
Production characteristics			
Pig number	<50 pigs	81	38.6
	50-100 pigs	99	47.1
	>100 pigs	30	14.3
Number of sows		8.11±7.863	
Number of hogs		40.31±43.03	
Number of piglets		24.14±18.51	

Table 3: *Farmers' awareness and attitudes towards the use of biogas in livestock farming.*

Indicators	Degree of perceived				
	1	2	3	4	5
When there are innovations in livestock farming, I will find a way to apply it	1.0	-	14.3	57.6	27.1
Among the livestock farmers I know, I am the one who often tries innovations	0.5	-	22.4	63.8	13.3
I like to experiment with innovations in livestock farming	0.5	-	1.4	81.0	17.1
Perceived innovativeness (PI)	4.046±0.477				
Biogas will reduce environmental pollution	0.5	0.5	12.4	36.2	50.5
Biogas will save time and waste treatment costs	-	1.0	2.4	77.6	19.0
Biogas will bring economic efficiency not only to pig farms but also to farming on farms	-	-	22.4	47.6	30.0
Biogas can be used for heating, cooking, or generating electricity for households	-	-	2.9	72.4	24.8
Perceived usefulness (PU)	4.200±0.475				
Biogas is easy to use on farms	0.5	-	12.9	63.8	22.9
Biogas can still be applied to small-scale farms	-	0.5	0.5	82.9	16.2
Biogas can be quickly learned to install and operate biogas	-	1.9	4.8	73.3	20.0
Biogas users can easily maintain and repair themselves	-	2.9	29.5	51.0	16.7
Perceived ease of use (PEU)	4.041±0.464				
Biogas can be used for both pig and livestock farms	0.5	-	27.1	57.6	14.8
Using biogas brings many benefits to households	-	0.5	20.0	64.3	15.2
Using biogas to protect the environment	-	-	17.1	58.1	24.8
Information/awareness (IA)	3.960±0.559				
Other households are using it	0.5	-	6.7	77.1	15.7
My relatives are using it at the farm	-	1.0	14.8	71.9	12.4
Encouraged by extension experts	-	0.5	15.7	54.3	29.5
Social influence (SI)	4.054±0.485				
Installation cost of biogas is not high	0.5	1.4	19.5	66.2	12.4
Biogas requires annual maintenance costs	-	1.0	9.5	76.2	13.3
Biogas brings more benefits than costs	-	-	16.2	66.7	17.1
Perceived cost (PC)	3.971±0.452				
I will use biogas for daily life	0.5	-	13.3	68.1	18.1
I will use biogas for other livestock	-	1.0	16.7	68.6	13.8
I will introduce biogas to relatives to use	-	-	2.9	79.5	17.6
Willingness to adopt	4.044±0.429				

extension experts. The average PC of biogas was 3.971. Most respondents (66.2%) thought installing biogas was not high, while 76.2% agreed that biogas required annual maintenance costs. Finally, the average willingness to adopt biogas was 4.044. Notably, 68.1% of farmers were willing to use biogas daily, and 79.5% would recommend biogas to relatives.

Table 4 shows that the correlation between age and gender with biogas adoption is very low and not statistically significant. Occupation has a positive correlation but is not statistically significant. Experience has a statistically significant positive correlation, suggesting that those with more experience in animal husbandry are more likely to adopt biogas. The number of pigs correlates, indicating that farms with more significant numbers of pigs may be more likely to adopt biogas. Income has a slight negative correlation, suggesting that lower-income households may be less likely to adopt biogas. Variables such as farming system education level did not correlate with biogas adoption. Strong correlations with biogas adoption were found for variables of training participation, PI, PU, and PEOU. This may indicate that farmers are more likely to adopt biogas. IA, SI, and PC were strongly correlated with biogas adoption, suggesting that information perception significantly impacts biogas adoption, especially when relatives have used biogas, and the cost of applying it is reasonable.

Table 4: *Spearman's correlation between social, economic, and cognitive factors with biogas adoption.*

Variables	Spearman's correlations	
	Results	Significant
Age	0.040	0.568
Gender	0.081	0.245
Ocuppation	0.131	0.059
Model	-0.072	0.302
Experience	0.182**	0.008
Education	-0.082	0.235
Pig number	0.137*	0.048
Labor	-0.022	0.756
Income	-0.137*	0.048
Purpose of raising	-0.143*	0.038
Trainning on biogas	0.522**	0.000
PI	0.668**	0.000
PU	0.395**	0.000
PEU	0.693**	0.000
IA	0.761**	0.000
SI	0.488**	0.000
PC	0.557**	0.000

Table 5: *Results of regression analysis of factors affecting willingness to adopt biogas system in pig farms.*

Variables	Regression analysis results				
	B	Std. Error	Beta	t	Sig.
Age	0.011	0.025	0.015	0.442	0.659
Gender	-0.036	0.029	-0.041	-1.258	0.210
Ocuppation	-0.088**	0.032	-0.103	-2.735	0.007
Model	0.058	0.038	0.050	1.525	0.129
Experience	-0.017	0.023	-0.023	-0.726	0.469
Education	-0.021	0.024	-0.028	-0.852	0.395
Pig number	0.019	0.021	0.031	0.916	0.361
Labor	0.018	0.025	0.023	0.724	0.470
Income	-0.006	0.022	-0.009	-0.262	0.794
Purpose of raising	-0.021	0.022	-0.032	-0.976	0.330
Trainning on biogas	0.041	0.038	0.044	1.104	0.271
PI	0.054	0.036	0.060	1.474	0.142
PU	-0.149**	0.053	-0.165	-2.819	0.005
PEU	0.036	0.060	0.039	0.610	0.543
IA	0.295**	0.045	0.384	6.556	0.000
SI	0.389**	0.049	0.439	7.960	0.000
PC	0.246**	0.053	0.259	4.620	0.000
Constant	0.679	0.205		3.309	0.001

The analysis Table 5 shows that some factors have a significant influence on biogas adoption. Notably, the occupation has a negative and statistically significant effect on biogas adoption (B = -0.088, Beta = -0.103, t = -2.735, p = 0.007), indicating that people working in other sectors may be less likely to adopt biogas than those specializing in pig farming. Similarly, PU significantly negatively affects biogas adoption (B = -0.149, Beta = -0.165, t = -2.819, p = 0.005). This may indicate that small-scale farmers who perceive biogas' usefulness are less likely to adopt biogas. In contrast, other factors such as IA (B = 0.295, Beta = 0.384, t = 6.556, $p < 0.001$), SI (B = 0.389, Beta = 0.439, t = 7.960, $p < 0.001$), and PC (B = 0.246, Beta = 0.259, t = 4.620, $p < 0.001$) have positive and significant effects on biogas acceptance. These results indicate that people who are aware of the benefits and information of biogas, as well as those who are influenced by society and feel that the cost is reasonable, tend to accept and use biogas more. Other factors such as age, gender, experience, education level, number of pigs, number of workers, income, farming purpose, biogas training, and perception of innovation did not show a statistically significant relationship with biogas acceptance in this model.

Technology constantly evolves and adapts in different places and times, driven by local circumstances and supported by social learning and progress (Glover *et al.*, 2019). Farm trials and farmer schools serve as a platform where social and technical innovation dynamics intersect in this continuous transformation. According to (Smith *et al.*, 2021), current reporting methods are inadequate to capture dynamic processes and unexpected outcomes. They focus on emphasizing farmers' active participation in the innovation process. In addition, identifying the impact of technology adoption is mainly done on large farms where the adoption rate of new technologies is high. In the current study, the results focus on the perceptions of smallholder livestock farmers through the extended TAM. However, previous studies suggested that when assessing influencing factors, priority should be given to determining sociological information (Guntoro *et al.*, 2023) and sociological factors also affect the production of pig farms (Qui *et al.*, 2020, 2021). In this study, male farmers are more dominant, with a higher average age and more experience. The results of this study are similar to those conducted on farmers in the Mekong Delta (Qui *et al.*, 2021, 2024).

The model shows that occupation, PU, IA, SI, and PC impact the farm's willingness to adopt the biogas system. Occupation has a negative impact on the willingness to adopt biogas. Farmers focusing on pig farming tend to be more willing to adopt biogas than those with other off-farm job activities. This can be explained by the fact that pig farmers have more time to learn about technology and news, as well as time to research and learn new information to support their farming activities. This increases the likelihood of adopting the biogas model. Previous studies have also shown that farmers with sideline activities often have difficulty focusing on agriculture and adopting new technologies due to time and resources being dispersed and negatively affecting agricultural production (Chang and Wen, 2011). According to previous research, if income from off-farm activities is more attractive than agriculture, farmers may be less interested in agriculture and spend more time and family labor on off-farm activities (Ahmed and Melesse, 2018; Chang and Wen, 2011).

For PU, the result shows farmers generally understand the benefits of biogas, as shown in previous research (Noi *et al*., 2022), but they are hesitant to adopt biogas on their farms. This may explain that although they understand that applying biogas can bring benefits such as generating electricity, supporting cooking, and protecting the environment, due to the small scale of farming, their application has not yet created distinct benefits for their farms. The cost of building a biogas digester, purchasing equipment, and installing it can be a significant obstacle for smallholders, especially those with low incomes and limited access to capital (Burg *et al*., 2021). It has also been noted that the main reasons for not adopting biogas are lack of labor and other inputs required to install and operate a biogas system; in addition, financial constraints and lack of space and livestock also account for a large part of the reasons for not investing in biogas (Ngo *et al*., 2017).

The results also demonstrate that information sources and perceptions of pig farmers influence biogas adoption. The findings of this study are consistent with those of Ntshangase *et al*. (2018) and Diaz *et al*. (2021), who highlighted that farmers regularly visited and supported by extension workers are more likely to adopt new technologies or farming practices. In this case, the opinions, views and evaluations of extension workers on technologies such as biogas are critical to farmers and able to influence their decisions on adopting these issues. In addition, when pig farmers have information about biogas, including its benefits and efficiency (Lin *et al*., 2022; Noi *et al*., 2022), the application will be more acceptable to farmers. In addition, farmers with complete information about biogas will better understand the operation, maintenance process, and possible technical problems. This helps them minimize risks and be more confident in applying new technology.

Farmers adopting new technologies on their farms are also partly influenced by society. Since an individual often lacks the resources, expertise, and experience to develop a biogas project without support, collaboration among actors is essential (Karlsson *et al*., 2017). In the current study, biogas adoption was primarily through neighboring farms or acquaintances. Using biogas when someone has used it increases confidence in operating and maintaining the system, thereby increasing the likelihood of successfully adopting this technology. According to Diaz *et al*. (2021), the opinions and views of friends, fellow farmers, relatives, or people close to them are essential to farmers' decisions to adopt technology. In addition, trust can help users overcome and accept the perceived risks associated with the uncertainty of new technology. According to the information recorded in the study of Cao *et al*. (2024), trust in new technology from individuals familiar with the trust plays a vital role in establishing initial trust and can influence subsequent stages. In information systems, social influence was found to have the most significant impact on trust. From there, social influence will partly affect technology adoption, in the current case, biogas.

In addition, the use of technology is also affected by cost. When pig farmers perceive that applying biogas will not cost much compared to their benefits (Noi *et al*., 2022), their willingness to apply biogas increases, as noted in other technology adoption studies. The diffusion of innovations results from individual decisions to adopt new technologies, often the result of comparing the benefits of these new technologies with the costs of adopting them. When deciding to adopt a specific technology, farmers will usually consider the impacts of adopting this technology on economic viability, and then farmers evaluate the benefits of increasing the use of the new technology (Admassie and Ayele, 2010; Zegeye *et al*., 2022). Other studies on technology adoption have also noted that most smallholder farmers are cost-conscious and tend to be sensitive to small fluctuations in the service fees of certain goods or technologies (Diaz *et al*., 2021). Therefore, when there is a high perception of the change in the cost when raising pigs in a profitable direction, pig farmers tend to apply biogas.

On the other hand, PEU did not record the influence of the remaining social factors, such as age, gender, occupation, education, and PI, on the willingness to apply biogas to the study. This is also similar to the words wrote in the study of Diaz *et al*. (2021), two primary constructs of TAM may not fully explain users' behavioral intention toward using technology.

Conclusions and Recommendations

The adoption of biogas by smallholder farmers is primarily determined by social influence, perceived information awareness, and perceived costs, as indicated in the extended TAM. A heightened understanding of these variables is positively associated with a greater inclination to embrace biogas. Notably, the study also discovered that farmers who specialized in pig farming and those who had a lesser perception of the benefits of biogas were more likely to embrace its adoption. Nevertheless, this analysis did not account for additional elements present in the extended TAM. To improve the adoption of biogas in pig farms, future legislative initiatives should focus on three crucial criteria: social influence, long-term costs, and communication strategies. Further studies on many social and economic issues must be conducted to enhance the willingness among smallholder farmers to adopt biogas. It includes investigating the influence of public policies, examining the disparities in farm sizes, and considering the significance of local conditions.

Acknowledgements

This study was supported by a grant from Program Asistensi Riset, Universitas Gadjah Mada, Indonesia in 2024 with a letter of acceptance No. 9437/UN1.P4/PT.01.02/2024. Besides, we acknowledge the support of time and facilities from Tra Vinh University (TVU) for this study.

Novelty Statement

This study focused on examination of factors affecting the decision to adopt biogas systems through the extended TAM. This study explores the social factors affecting the acceptance of biogas technology, in contrast to prior research that mostly emphasized its environmental advantages. The study specifically analyzes the behaviors and attitudes of smallholder farmers in the region, offering practical policy recommendations to enhance the sustainable implementation of biogas systems.

Author's Contribution

Budi Guntoro: Conceptualization, Methodology, Validation, Writing review and editing, Supervision.
Nguyen Hoang Qui: Conceptualization, Methodology, Software, Validation, Formal analysis, Writing original draft preparation, Writing review and editing.
Ahmad Romadhoni Surya Putra: Conceptualization, Methodology, Software, Validation, Formal analysis, Writing original draft preparation, Writing review and editing
Nguyen Thi Anh Thu: Software, Investigation.
Nguyen Van Vui: Software, Investigation, Supervision.

Conflict of interest

The authors have declared no conflict of interest.

References

Admassie, A. and G. Ayele. 2010. Adoption of improved technology in Ethiopia. Ethiop. J. Econ. 19(1): 155-179. https://doi.org/10.4314/eje.v19i1.71416

Agarwal, R. and J. Prasad. 1998. A conceptual and operational definition of personal innovativeness in the domain of information technology. Inf. Syst. Res., 9(2): 204-215. https://doi.org/10.1287/isre.9.2.204

Ahmed, M.H. and K.A. Melesse. 2018. Impact of off-farm activities on technical efficiency: Evidence from maize producers of eastern Ethiopia. Agric. Food Econ., 6(1): 3. https://doi.org/10.1186/s40100-018-0098-0

Burg, V., K.G. Troitzsch, D. Akyol, U. Baier, S. Hellweg and O. Thees. 2021. Farmer's willingness to adopt private and collective biogas facilities: An agent-based modeling approach. Resour. Conserv. Recycl. 167: 105400. https://doi.org/10.1016/j.resconrec.2021.105400

Busch, G., M. Gauly and A. Spiller. 2018. Opinion paper: What needs to be changed for successful future livestock farming in Europe? Animal, 12(10): 1999-2001. https://doi.org/10.1017/S1751731118001258

Caffaro, F. and E. Cavallo. 2019. The effects of individual variables, farming system characteristics and perceived barriers on actual use of smart farming technologies: Evidence from the Piedmont region, northwestern Italy. Agriculture, 9(5): 111. https://doi.org/10.3390/agriculture9050111

Cao, J., H. Feng, Y. Lim, K. Kodama and S. Zhang. 2024. How social influence promotes the adoption of mobile health among young adults in China: A systematic analysis of trust, health consciousness, and user experience. Behav. Sci., 14(6): 498. https://doi.org/10.3390/bs14060498

Chang, H.H. and F.I. Wen. 2011. Off-farm work, technical efficiency, and rice production risk in Taiwan. Agric. Econ., 42(2): 269-278. https://doi.org/10.1111/j.1574-0862.2010.00513.x

Davis, F.D., 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quart., 13(3): 319-340. https://doi.org/10.2307/249008

Diaz, A.C., N. Sasaki, T.W. Tsusaka and S. Szabo. 2021. Factors affecting farmers' willingness to adopt a mobile app in the marketing of bamboo products. Resour. Conserv. Recycl. Adv. 11: 200056. https://doi.org/10.1016/j.rcradv.2021.200056

Glover, D., J. Sumberg, G. Ton, J. Andersson and L. Badstue. 2019. Rethinking technological change in smallholder agriculture. Outlook. Agric., 48(3): 169-180. https://doi.org/10.1177/0030727019864978

GSO, 2021. Socio-economic situation report in the fourth quarter and 2021. https://www.gso.gov.vn/en/data-and-statistics/2022/01/socio-economic-situation-in-the-fourth-quarter-and-2021/. Accessed Sep 3 2024.

Guntoro, B., A. Triatmojo, B. Ariyadi and N. Qui. 2023. Risk analysis in cattle farmers prevention practices of anthrax and foot and mouth disease in yogyakarta province, Indonesia. Adv. Anim. Vet. Sci., 11(6): 987-997. https://doi.org/10.17582/journal.aavs/2023/11.6.987.997

Jeong, B.K. and T.E. Yoon. 2013. An empirical investigation on consumer acceptance of mobile banking services. Bus. Manage. Res., 2(1): 31-40. https://doi.org/10.5430/bmr.v2n1p31

Karlsson, N.P.E., F. Halila, M. Mattsson and M. Hoveskog. 2017. Success factors for agricultural biogas production in Sweden: A case study of business model innovation. J. Clean. Prod., 142(4):2925-2934. https://doi.org/10.1016/j.jclepro.2016.10.178

Levine, D.M. and D.F. Stephan. 2010. Even you can learn statistics: A guide for everyone who has ever been afraid of statistics. 2nd ed. USA: FT Press, New Jersey.

Lin, C.Y., K.Y. Chau, M. Moslehpour, H.V. Linh, K.D. Duong and T.Q. Ngo. 2022. Factors influencing the sustainable energy technologies adaptation in ASEAN countries. Sustain. Energy Technol. Assess., 53(C): 102668. https://doi.org/10.1016/j.seta.2022.102668

Michels, M., W. Fecke, J.H. Feil, O. Musshoff, J. Pigisch and S. Krone. 2020. Smartphone adoption and use in agriculture: Empirical evidence from Germany. Precis. Agric., 21: 403-425. https://doi.org/10.1007/s11119-019-09675-5

Ngo, T.T.T., S.N. Tran, V.C.N. Nguyen and B. Jan. 2017. Factors Influencing the Adoption of small-scale biogas digesters in developing countries – empirical evidence from Vietnam. Int. Bus. Res., 10(2): 1-8. https://doi.org/10.5539/ibr.v10n2p1

Noi, S., M. Jelínek and H. Roubík. 2022. Small-scale biogas plants in Vietnam: How are affected by policy issues? Ecol. Quest., 33(4): 111-129. https://doi.org/10.12775/EQ.2022.037

Ntshangase, N.L., B. Muroyiwa and M. Sibanda. 2018. Farmers' Perceptions and Factors Influencing the Adoption of No-Till Conservation Agriculture by Small-Scale Farmers in Zashuke, KwaZulu-Natal Province. Sustainability, 10(2): 555. https://doi.org/10.3390/su10020555

Pithoon, T., S. Tatcha and T. Danai. 2020. Integrating trust into the technology acceptance model: The case of mobile banking adoption in Myanmar. Panyapiwat J., 12(3): 107-119.

Putri, A., Purwanto and H. Purnaweni. 2020. Perception of the community on the use of biogas as alternative energy (Case study: Jetak Village, Getasan sub district). Pages 012045 in life and environmental sciences academics forum 2018. Ratna, Y., M. Chris and N. Ryota eds. IOP Conference Series: Earth and Environmental Science, West Java, Indonesia. https://doi.

org/10.1088/1755-1315/481/1/012045

Qui, N.H., B. Guntoro and S.P. Syahlani. 2020. The social profile, constraints, and its impact on swine herd size in Tra Vinh Province, Vietnam. Trop. Anim. Sci. J., 43(4): 385-390. https://doi.org/10.5398/tasj.2020.43.4.385

Qui, N.H., B. Guntoro, S.P. Syahlani and N.T. Linh. 2021. Factor affecting the information Sources and communication channels toward pig farmer's perception of African swine fever in Tra Vinh province, Vietnam. Trop. Anim. Sci. J., 44(2): 248-254. https://doi.org/10.5398/tasj.2021.44.2.248

Qui, N.H., N.T.A. Thu and N.T. Linh. 2024. The awareness and behaviour's farmer towards highly pathogenic avian influenza prevention in Tra Vinh, Vietnam. J. Indones. Trop. Anim. Agric., 49(2): 169-180. https://doi.org/10.14710/jitaa.49.2.169-180

Rezaei, R., L. Safa and M.M. Ganjkhanloo. 2020. Understanding farmers' ecological conservation behavior regarding the use of integrated pest management- an application of the technology acceptance model. Glob. Ecol. Conserv., 22: e00941. https://doi.org/10.1016/j.gecco.2020.e00941

Rind, M., M. Hyder, A.S. Saand, T. Alzabi, H. Nawaz and I. Ujan. 2017. Impact Investigation of perceived cost and perceived risk in mobile commerce: analytical study of Pakistan. Int. J. Comp. Sci. Netw. Secur., 17(11): 124-130.

Roubík, H., J. Mazancová and J. Banout. 2018. Current approach to manure management for small-scale Southeast Asian farmers-Using Vietnamese biogas and non-biogas farms as an example. Renew. Energy, 115(2018): 362-370. https://doi.org/10.1016/j.renene.2017.08.068

Roubík, H., J. Mazancová, L. Phung and D. Dung. 2017. Quantification of biogas potential from livestock waste in Vietnam. Agron. Res., 15(X): 540-552.

Smith, H.E., S.M. Sallu, S. Whitfield, M.F. Gaworek-Michalczenia, J.W. Recha, G.J. Sayula and S. Mziray. 2021. Innovation systems and affordances in climate smart agriculture. J. Rural Stud., 87: 199-212. https://doi.org/10.1016/j.jrurstud.2021.09.001

Truc, N.T.T., T.S. Nam, N.V.C. Ngan and J. Bentzen. 2017. Factors influencing the adoption of small-scale biogas digesters in developing countries–Empirical evidence from Vietnam. Int. Bus. Res., 10(2): 1-8. https://doi.org/10.5539/ibr.v10n2p1

Wu, J.H. and S.C. Wang. 2005. What drives mobile commerce? An empirical evaluation of the revised technology acceptance model. Inf. Manage., 42(5): 719-729. https://doi.org/10.1016/j.im.2004.07.001

Zegeye, M.B., A.H. Fikire and A.B. Assefa. 2022. Impact of agricultural technology adoption on food consumption expenditure: evidence from rural amhara region, Ethiopia. Cogent. Econ. Finance, 10(1): 2012988. https://doi.org/10.1080/23322039.2021.2012988