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Pre- and Post-Adoption Beliefs about the Diffusion and Continuation of Biogas-Based Cooking Fuel Technology in Pakistan

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Abstract: A high level of acceptance and adoption is necessary to facilitate the widespread utilization of renewable energy technologies for cooking, as such utilization is essential for displacing the population's massive dependence on fossil fuels and solid biomass. Economic and demographic aspects have been the focus of recent literature in exploring the adoption phenomenon of biogas technology. However, literature to date has given little attention to the behavioral factors and the perceptions of the end-users. Our study does not only include behavioral factors, but it employs a hybrid model to explore the continued attentions of users based on their post-adoption beliefs and performance expectations. Using a survey conducted in Pakistan in 2017, the study conducts a multivariate analysis through structural equation modeling to measure the effect of pre- and post-adoption beliefs and expectation on adoption and the continuing intention of households towards biogas technology. Results show that the acceptance of the households towards biogas technology is highly influenced by their perceptions on the benefits, as well as their trust in the technology. The perceived cost and risk attached to the technology are found to be negatively correlated with the acceptance. Households' intentions to continue the use of biogas technology is highly influenced by the satisfaction level of the users of biogas technology. With the integrated model of adoption and continuation, the study illustrates the dynamic process in obtaining a deeper understanding of a user's behavior to better formulate the policies for increasing the rate of technology adoption.

Keywords: adoption; continue intention; perceived values; drivers; inhibitors

1. Introduction

Renewable energy technologies address environmental problems to significant degrees and can contribute to sustainable resource use. The goal of low carbon and energy sufficient society can be met through accelerated development of and transition toward such technologies. However, the uptake of these technologies is relatively slow, and literature has not fully explored the reasons for slow adoption processes or even dis-adoption. Among other renewable energy technologies, household biogas digesters are a prominent example of sustainable technology that has multiple benefits—not only in terms of environmental protection but also in social and economic contexts [1–4].

In developing countries, such as Pakistan, renewable fuel technologies for cooking have not been used sufficiently and consistently to the degree where they can displace traditional cooking technologies. Almost 75% of the Pakistani rural population use biomass and fossil energy as cooking fuel. These households directly burn crop residues, woods, shrubs, and animal manure in their kitchens; such practices pose health risks through indoor pollution to the families using the fuels. Moreover, these fuel sources are also incombustible and are leading causes of greenhouse gases and black carbon that affect the environment [5]. It is, therefore, crucial to use biogas technology as an alternative energy source for domestic cooking because it is eco-friendly and does not threaten the health of families.

Biogas technology is not a new concept in Pakistan. Although it was introduced as early as the 1970s, the technology has not gained much success due to high investment costs, reduction in government subsidy, and lack of awareness due to poor marketing. Because of these factors, the adoption rate of the technology remains low in Pakistan compared to other neighboring countries [6]. Even if households could afford and have access to modern cooking fuel technologies, such as biogas, they tend to continue using traditional fuels for cooking [7]. Therefore, it is a major challenge to achieve a long-term, stable, and successful transition from traditional fuels, especially in developing countries with health and environment consequences that are alarming [8].

As seen in the case of biogas technology, the real success of any innovative technology does not only lie in its existence and development but also in its widespread use. Society cannot reap the benefits of any technology until it is fully and widely diffused. In this regard, sometimes, there is a place for policies, institutions, social norms, and human behavior to play an important role [9]. The same technology can have different adoption and acceptance rates in different countries due to different policies and cultural boundaries [10]. In certain places, households have found it difficult to adapt to new technologies due to previous practices, and local manufacturers of traditional technologies often slow down the diffusion process when they view new technologies as a threat to their running businesses [11,12]. When facing such challenges, a conducive environment in support of technology and social networks could help in changing people's perceptions.

The overall objective of this research is to examine the barriers and obstacles in clean cooking energy transition through the lens of behavior change that occurs at the household level. The study focuses on this transitional process in two directions. First, the focus of this research is on using behavioral constructs rather than objective indicators, such as technical characteristics, market conditions, government regulations, or demographic factors, to explain the transition process. For behavioral indicators, we consider behavioral science literature, which suggests how human actions and decisions are more influenced by reality-driven perceptions and intuitions rather than objective factors [13]. For example, an accident caused by liquefied petroleum gas (LPG) in an Indian village turned villagers against the use of LPG as they considered it unsafe, irrespective of the fact that LPG is considered to be safe technology [14]. In the same way, the education level in terms of years of schooling did not independently and directly affect the decision of transitioning towards clean cooking technologies; rather, it indirectly facilitates individuals to have a better understanding of the risks and consequences of traditional cooking fuel technologies and enable them to make rational choices [15]. Therefore, it is more important to consider the beliefs that individuals have regarding the compatibility of the technology from the point of view of their skills instead of their years of schooling as an enabling factor. Another important factor is the cost of the technology, which is also seen as an important determinant in the decision-making process [16–18]; however, instead of considering the monetary price of the technology, we may obtain a better understanding of the reality if we examine how individuals perceive the price of the technology as it is compared to the available alternatives. Therefore, the objective in looking at these behavioral constructs is to utilize the constrained resources—such as promotional campaigns and advertisements—to focus on the factor that has direct implications for the widespread adoption of the technology.

Second, we also consider the post-adoption beliefs of the households, as these beliefs are crucial for the continuation of the technology in the long-term because the overall success of new technology can only be observed if it is fully diffused. Adoption is considered the initial step in the acceptance of any technology, but the true diffusion and actual success of the technology depend on its continued use [19].

The ineffective and irregular use of technology in the long-term often leads to failure of that technology, and one cannot classify such technology as a success [12]. The continuance phenomenon is different from initial adoption, as initial adoption is based on the expectations; in continuation, households form their perceptions based on experience and satisfaction from experience, thereby leading them to the continued use of the technology. Both situations are so different that in many cases, households stop using the technology after initial adoption due to various reasons, which not only cause the number of current adopters to decrease but also reduce the probability of future adoption when negative perceptions are created for the later adopters [20]. Various technology adoption studies mostly focus on the initial acceptance of the technology. A substantial segment of literature based on diffusion theories (e.g., technology acceptance model, the theory of planned behavior, the theory of reasoned action) has focused on the variables that motivate consumers to initially adopt the technology [16–18]. Among renewable energy literature, especially in the case of biogas technology, no study has empirically examined the factors that explain the continuing use of biogas-based cooking fuel technology from the perspective of households.

This study seeks to empirically examine the role of pre- and post-behavioral factors in biogas technology adoption and its continuation in the context of Pakistan. The current research contributes to a more robust understanding of the uptake of biogas technology by formulating a comprehensive integrated model that addresses the research gap. In this research, we evaluate the explanatory power of subjective beliefs based on the general model of perceived value and expectation confirmation theory (ECT) to understand the biogas technology adoption decision and the continuation decision of households through their pre- and post-adoption beliefs and perceptions about technology attributes. The study is an addition to existing theoretical and empirical literature, as it provides an integrated model that explains the adoption and continuation phenomenon in a single model. This hybrid model can provide a more comprehensive explanation and understanding of consumer behavior in biogas technology adoption.

The remainder of the article is structured as follows: Section 2 explains the theories and literature based on behavioral factors to address the technology adoption and diffusion phenomenon. Section 3 comprises survey methodology and variables description, followed by Sections 4 and 5 where findings are given with a discussion. The last section concludes the research.

2. Theoretical Background

In this section, we review the relevant theories and literature to explain the biogas technology adoption phenomenon with an integration of the actors' continuation beliefs regarding the technology. Focusing on behavioral factors in the adoption models is not new in economics and psychological literature [20–24]. This idea comes from the fact that human behavior is not merely explained by objective factors, but that an individual's beliefs and perceptions about the consequences of decisions also have a bearing on decision-making processes regarding technology adoption. Compared to objective indicators, beliefs play a rather direct role in the decision of adoption [14]. Renowned adoption theories (e.g., the theory of reasoned action, the theory of planned behavior, value belief and norm theory, and technology acceptance model) focus on human behavior components and are widely used in literature for a diverse range of technologies, including renewable energies [19,25–32]. These theories highlight the behavioral factors' subjective beliefs and norms, perceived usefulness, perceived ease to use, attitude, and intentions as important for making decisions to adopt technologies. However, the constructs in these theories are by their nature more as driving factors, while the role of inhibiting factors is rather ignored. Therefore, this study also incorporates the inhibiting factors—along with facilitators and drivers—which serve as barriers in the technology adoption stage. We named this the pre-adoption stage, for which a general model of perceived value is used as the theoretical foundation [33–35]. This model postulates the importance of both the positive and negative perceptions of actors in forming beliefs about the technology. We further assume that these pre-adoption perceptions guide potential adopters when they decide on adoption or confirmation of biogas technology. Moreover, we assume that perceptions about benefits, trust, and ease to use technology play a positive role in the adoption/confirmation, and that perceptions about cost and risk are included as inhibiting factors in this process of decision-making.

In the post-adoption stage, we explore the factors behind continuance intention using the expectation confirmation model (ECM) for theoretical reasoning. In marketing and information technology research, ECM is employed to examine the satisfaction level of the consumers and their intention to repurchase a certain commodity or service [36–38]. ECM postulates that the pre-usage expectations lead consumers to form certain perceptions about the performance of the product or service. Then after the actual usage, they compare the pre-usage expectation and their performance perceptions. If their perceptions about performance are higher than their expectations, they confirm the technology. The higher degree in the confirmation stage shows the validation of the fact that users are more satisfied with the product. Finally, the level of satisfaction with the product or technology determines a consumer's intention to continue the use of that particular product/technology. Information Systems research uses this model widely and applies it to other technologies and services, as well as other adoption models.

The proposed framework of the study is a hybrid framework of two perspectives—namely adoption and continuation—in which the general model of perceived value and the ECM framework are applied, as depicted in Figure 1.

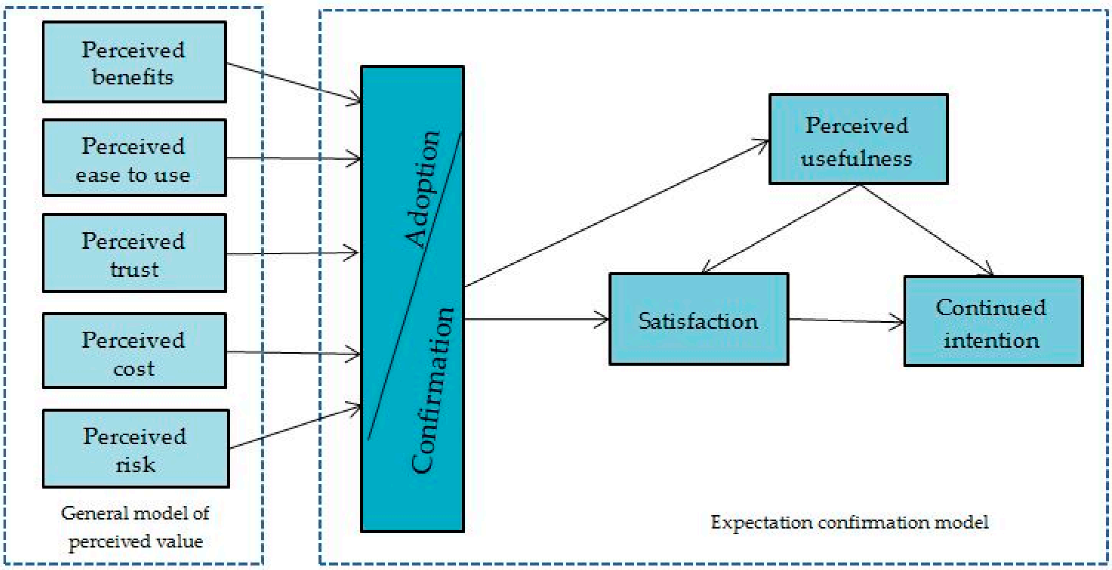

Figure 1. A Proposed integrated model for adoption and continuing intention.

2.1. *Pre-Adoption Stage*

Following the driving and inhibiting indicators, consumers evaluate the biogas technology for actual adoption or dis-adoption. Self-perception theory and the model of perceived value both provide theoretical reasoning for this, which postulate that consumers observe their behavior in forming their beliefs and attitude towards technology [39].

2.1.1. Drivers of the Adoption

Perceptions of the benefits of technology are subjective expectations about the positive implications of using technology. If users believe a technology/innovation to be more efficient and effective, the probability of adoption of that technology/innovation will likely increase [33]. Benefits from biogas technology are both tangible and intangible [40]. Tangible or direct benefits include a reduction in fuel cost and the provision of organic fertilizer; intangible benefits consist of improved health due to less smoke, a cleaner home due to an absence of residue, a greater convenience of cooking food with less time and effort, and fewer hazardous effects on the environment [41]. These positive perceptions about biogas technology may motivate households to adopt the technology.

Another potential driver in this confirmation/adoption process is the perceptions about the ease to use the technology. This refers to the belief that a particular technology requires less effort to learn and use and is relatively simple to understand [42]. This cognitional factor implies that there is an increased chance of users adopting a technology which they perceive as user-friendly compared to one they perceive as less user-friendly. Perception is an important construct in the technology adoption model (TAM); however, it is argued that the perception of the ease to use technology has higher importance at the early stage of adoption and that this importance tends to diminish in later stages [43]. The reason is that over time, users become familiar with the technology/innovation, and they learn to operate or use it in later stages. Another concern that potential users of new technology may have is perceived trust. Before the usage and experience of new technology, trust plays an important role in forming people's beliefs. Specifically, trust is defined as a cognitive state of positive anticipation that affects the user's perceptions to adopt the technology [44]. Several studies found that trust generates from the surrounding atmosphere and comes from other users in society. A strong positive association between perceived trust and adoption of technology is found in numerous studies for various technologies [45–47]. Based on these above drivers, we hypothesize the following:

Hypotheses H1–H3. *The drivers' perceived benefits, perceived ease to use, and perceived trust have a positive effect on the adoption of biogas cooking fuel technology.*

2.1.2. Inhibitors in the Adoption

Perceived risks are the suspicions that users have about the functioning and performance of the technology. Additionally, these are the feelings that the new technology would fail to give the expected benefits and the insecurity about the technical functioning of the technology. These risks make consumers less receptive to new technology and slow down the process of adoption [24,39,46]. Cost is another concern that consumers have regarding new technology or innovation; it does not only include the initial investment cost but the maintenance cost, as well as the opportunity cost of time [48]. Prior studies have indicated the inhibiting influence of cost of biogas technology on technology adoption [49–51]. Consequently, we hypothesize the following:

Hypotheses H4–H5. *Inhibitors (namely perceived cost and perceived risk) have a negative effect on the adoption of biogas cooking fuel technology.*

2.2. Post-Adoption Stage

Post-adoption influencing factors for long-term sustained use are less explored in renewable energy literature since the focus remains on the initial uptake, sales, or challenges in short term use. The ECM explains the long-term continuation phenomenon through five paths. Satisfaction in the ECM is a psychological state in which consumers compare the prior expectations with the actual performance of the technology. They feel more satisfied if they considered their prior expectations to be met or be greater than the expected performance. In ECM, two factors are considered to be the potential determinant of a consumer's satisfaction, namely confirmation and perceived usefulness. A confirmation has a direct effect on satisfaction; it states that users' confirmation/adoption of the technology is the realization of expected benefits. Perceived usefulness is an important construct in TAM, and it is defined as a practical benefit that consumers observe when using technology. The more users expect technology to be useful, the more likely the consumers will be satisfied with the technology. This perceived usefulness also has a direct link to continuing intentions, where it is hypothesized that if users consider a technology to be more useful, they will more likely continue using that technology in the long run. Lastly, users' satisfaction with biogas technology has a positive effect on their intentions to continue using it in the future [20,37,52]. Based on the paths described above, we derived the following hypotheses from the ECM:

Hypotheses H6. *Adoption/confirmation of biogas cooking fuel technology has a positive effect on usefulness.*

Hypotheses H7. *Adoption/confirmation of biogas cooking fuel technology has a positive effect on satisfaction.*

Hypotheses H8. *Perceived usefulness of biogas cooking fuel technology has a positive effect on satisfaction.*

Hypotheses H9. *Perceived usefulness of biogas cooking fuel technology has a positive effect on continuance intentions.*

Hypotheses H10. *Satisfaction with biogas cooking fuel technology has a positive effect on continuance intentions.*

3. Materials and Methods

3.1. Survey Development and Data Collection

The data used in this study stemmed from a structured survey conducted with owners of biogas digesters who have either fully replaced their traditional cooking fuel sources for biogas technology or have partially switched to biogas digesters while still using traditional energy sources. There was no restriction for age and education of the respondents. The data were collected from 330 households in June and July 2017 from three districts of central Punjab, specifically Faisalabad, Sargodha, and Jhang. These districts are of interest because 50% of the biogas adopters in Punjab belong to these three districts. Multistage sampling technique was used for the selection of the required sample, where in the first stage, Punjab province was selected through purposive sampling. This province has the largest number of livestock and favorable temperature, which are both pre-requisites for the operation of domestic biogas digesters. In the second stage, three districts were purposefully selected within Punjab; they were selected because of the concentration of large numbers of adopters in these areas. In the final stage, an equal number of households from these areas were selected through random sampling. Figure 2 shows a detailed sampling frame.

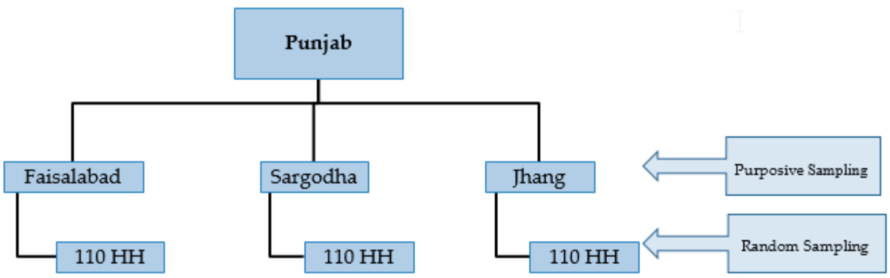

Figure 2. Sampling frame. Source: Own illustration. HH = Households.

The questionnaire that was developed for the collection of data comprised of three parts. The first part included participants' demographic information, while the second and third parts consisted of general information about the biogas technology, as well as the level of agreement and disagreement of participants' on different aspects of the technology.

3.2. Variables Measurement

The variables measurement came from a selection and adaptation of survey items that were found in the literature; these items were reported during discussions with experts and researchers in the field of consumer behavior (see Appendix A). A five-point Likert scale ranging from 1 (strongly agree) to 5 (strongly disagree) was used for all items except for demographic variables. Literature has recommended using the five-point Likert scale to increase the response rate and response quality, and studies have also argued that the scale decreases the confusion and frustration level in the respondents [53–55].

Pertaining to the adoption stage, a three-item scale measuring the variables *perceived ease to use* was adapted from Davis et al. [21]. The scales of the variables *perceived benefits, perceived risk, and perceived cost* had three items each and were adapted from Park and Ohm (2014) [44]. The scales of *confirmation, satisfaction, and continued intention* were adapted from Bhattacherjee [20]. The *perceived trust* also had three items and was adapted from Kim et al. (2014) [56]. For *perceived usefulness,* a three-item scale was also adapted from Venkatesh et al. (2011) [57].

In the next phase, we refined the construct items by testing the measurement model using data from 28 households that were collected in a pilot stage. AMOS software Version 24 IBM Corp, Armonk, NY was used in the analysis.

4. Results

This research empirically examines the proposed hybrid model of adoption and continuation of biogas technology from the household's perspective, and a two-step modeling technique serves for hypotheses testing. In the first phase, a measurement model and a confirmatory factor analysis (CFA) confirm the validity and reliability of the scales, and in the second stage, a structural model assesses the hypothesized relations.

4.1. Demographic Characteristics

Table 1 shows the demographic and socio-economic characteristics of the respondents in the study area. The age distribution of the sample respondents ranges from 18 to 80 years. From a total of 330 respondents, 171 (more than 50%) are above 40 years, which is higher than the average age (34.1 years) in Pakistan [58]. The income distribution of the respondents shows a small percentage of respondents with low income (7.6%) in the sample. The same trend exists in land ownership, which shows that 4.2% of respondents do not own the agricultural land. This implies that biogas technology is adopted mainly by the average- to the high-income group due to high investment cost [59–61].

Table 1. Socio-economic and demographic characteristics of the study sample (N = 330).

Variables	Characteristics	Count	Sample Percentage
Age	18–30	58	17.6
	31–40	101	30.6
	41–50	87	26.4
	<50	84	25.5
Education	No education	33	10.0
	Primary (1–5)	54	16.4
	Secondary (6–12)	193	58.5
	Higher	50	15.2
Income (PKR) [1]	>20,000	25	7.6
	20,001–40,000	104	31.5
	40,001–60,000	77	23.3
	60,001–80,000	26	7.9
	<80,001	98	29.7
Land holdings (Acres)	No land	14	4.2
	1–25	255	77.3
	26–50	41	12.4
	<51	20	6.1

[1] One US$ is equal to 150 Pakistani rupees (PKR).

4.2. Measurement Model

Tables 2 and 3 show the results from the CFA method of analysis, which is used for checking the validity and reliability of the proposed measurement model.

Table 2. Results of measurement model (with factor loads, CR (Composite Reliability), AVE (Average Variance Extracted), and Cronbach's alpha).

Factor	Measurement Item	Estimates	CR	AVE	Alpha
Perceived cost	PC1	0.92	0.94	0.84	0.91
	PC2	0.91			
	PC3	0.92			
Perceived risk	PR1	0.83	0.88	0.71	0.81
	PR2	0.82			
	PR3	0.88			
Perceived benefits	PB1	0.88	0.88	0.71	0.90
	PB2	0.87			
	PB3	0.88			
Perceived ease of use	PEU1	0.90	0.93	0.81	0.89
	PEU2	0.92			
	PEU3	0.87			
Perceived trust	PT1	0.89	0.89	0.73	0.83
	PT2	0.85			
	PT3	0.83			
Perceived usefulness	PU1	0.89	0.93	0.82	0.94
	PU2	0.92			
	PU3	0.91			
Confirmation	CON1	0.80	0.86	0.67	0.86
	CON2	0.84			
	CON3	0.81			
Satisfaction	S1	0.84	0.94	0.69	0.86
	S2	0.82			
	S3	0.84			
	S4	0.82			
Continued intention	CI1	0.87	0.90	0.76	0.86
	CI2	0.82			
	CI3	0.87			

Note 1: PC = Perceived cost, PR = Perceived risk, PB = Perceived benefits, PEU = Perceived ease of use, PT = perceived trust, PU = Perceived usefulness, CON = Confirmation, S = Satisfaction, CI = Continued intention. Note 2: All the factor loadings are significant at 0.05 level. Note 3: CMIN/df (Chi-square/Degree of Freedom) = 1.37, GFI (Goodness-of-Fit Index) = 0.92, AGFI (Adjusted Goodness-of-Fit Index) = 0.90, NFI (Normed Fit Index) = 0.90, CFI (Comparative Fit Index) = 0.98, RMSEA (Root Mean Square Error of Approximation) = 0.03.

All factor loads are significant and greater than the threshold of 0.5 [62]. The fit indices of the measurement model are quite satisfactory with CMIN/df = 1.37, comparative fit index (CFI) = 0.98, and root mean square error of approximation (RMSEA) = 0.03. The results show that the composite reliability (CR) and Cronbach's alpha values exceed the threshold values of 0.7 and that the average variance extracted (AVE) is greater than the threshold value of 0.5. Furthermore, the correlation among variables is less than the square root of the AVE, which confirms the uniqueness of the constructs. The diagonal values in Table 3 are higher than inter-construct correlation values, thus confirming the discriminate validity. In short, the overall results of the measurement model are in support of reliability, internal consistency, convergent validity, and discriminant validity [63–66].

Table 3. Results of the Fornell–Larcker validation.

Constructs	PC	PR	PB	PEU	PT	PU	CON	CI	S
PC	(0.92)								
PR	0.012	(0.84)							
PB	−0.086	−0.077	(0.84)						
PEU	0.069	0.129	0.059	(0.90)					
PT	−0.022	−0.056	0.182	0.010	(0.85)				
PU	−0.043	−0.114	0.118	−0.141	0.109	(0.91)			
CON	−0.149	−0.185	0.527	0.150	0.181	0.152	(0.82)		
CI	−0.004	−0.118	0.221	0.056	0.046	0.423	0.276	(0.85)	
S	0.000	−0.162	0.114	−0.018	−0.024	0.203	0.209	0.141	(0.83)

Note 1: PC = Perceived cost, PR = Perceived risk, PB = Perceived benefits, PEU = Perceived ease of use, PT = Perceived trust, PU = Perceived usefulness, CON = Confirmation, S = Satisfaction, CI = Continue intention. Note 2: Values in "( )" indicate the square root value of AVE of given variables, while the off-diagonal elements represent the correlation coefficients.

4.3. Structural Model

The hypothesized relational paths are assessed by estimating the structural model based on its ability both to test the multiple relationships simultaneously and also to compute the overall validity of the model [62]. The goodness-of-fit indices presented in Table 4 indicate an acceptable model fit.

Table 4. Fit statistics for the structural model.

Fit Indicators	Recommended Values	Structural Model Values
χ^2 ratio	≤5.00	1.75
CFI	≥0.90	0.96
AGFI	≥0.90	0.95
GFI	≥0.90	0.98
RMSEA	≤0.06	0.04

Table 5 and Figure 3 show the results of the structural model. The path analysis results support nine of the tested hypotheses out of ten. The first five tests the adoption model based on pre-adoption perceptions, and all five are found to be significant. H_1, which predicts a positive relationship between perceived benefits and the adoption/confirmation of the technology, is statistically significant ($\beta = 0.48$; $p < 0.01$). The study found H_2, which hypothesizes a positive relationship between perceived ease of use and adoption, to be significant also ($\beta = 0.13$; $p < 0.01$). H_3, which proposes the same positive relationship between perceived trust and biogas technology adoption, is also significant ($\beta = 0.08$; $p < 0.10$). H4 and H5, which are the inhibitors, show a negative relationship of perceived cost ($\beta = -0.12$; $p < 0.05$) and perceived risk ($\beta = -0.16$; $p < 0.01$) with the adoption.

Table 5. Statistical analysis of path coefficients (original model).

H	Hypothesized Path	Standardized Coeff.	*p*-Value	Remarks
H1	CON←PB	0.48	0.000	Supported
H2	CON←PEU	0.13	0.001	Supported
H3	CON←PT	0.08	0.078	Supported
H4	CON←PC	−0.12	0.011	Supported
H5	CON←PR	−0.16	0.000	Supported
H6	PU←CON	0.28	0.000	Supported
H7	S←CON	0.18	0.001	Supported
H8	S←PU	0.09	0.001	Not supported
H9	CI←PU	0.40	0.000	Supported
H10	CI←S	0.15	0.003	Supported

Note: PC = Perceived cost, PR = Perceived risk, PB = Perceived benefits, PEU = Perceived ease of use, PT = Perceived trust, PU = Perceived usefulness, CON = Confirmation, S = Satisfaction, CI = Continue intention.

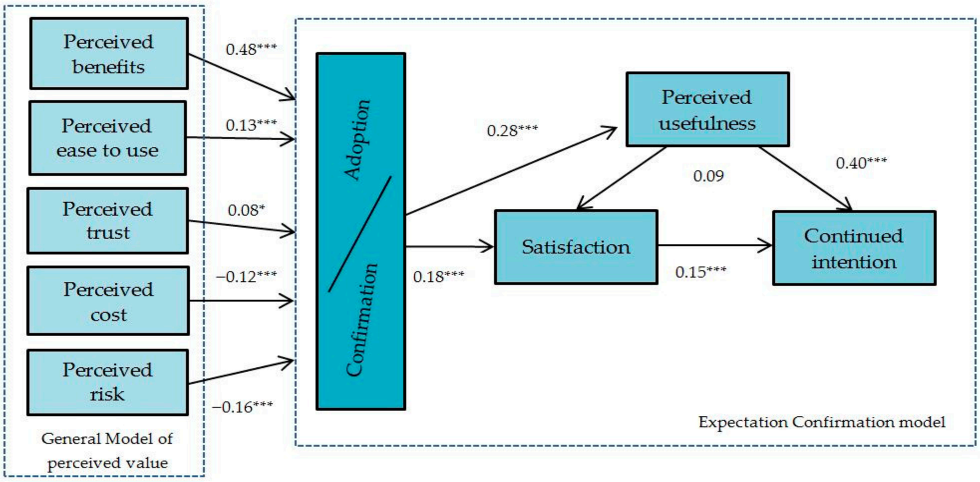

Figure 3. Results of the proposed model.

The results of the analysis on the continuation intention based on post-adoption beliefs support the hypotheses of the ECM model, except for the relationship between perceived usefulness and satisfaction. This hypothesis is not supported by the study sample. Adoption is found to be the positive and significant determinant in satisfaction ($\beta = 0.18$; $p < 0.01$). In terms of predicting the intention to continue using biogas technology, the perceived usefulness and satisfaction about the technology show a positive and significant effect.

5. Discussion

The intentions and the continuation to use and adopt biogas cooking fuel technology have not yet been jointly analyzed in one single study. Technology adoption literature has often considered these phenomena separately; however, neither intentions nor continuation alone can explain the diverse subject of technology adoption. The integrated model of adoption and continuation presented in this paper aims to fill this existing gap in the literature and provide a sound basis for energy policymaking.

The results confirm the characteristics that are perceived as relevant by potential users and are postulated in the current research for explaining biogas technology adoption. Regarding the driving factors, the perceptions that households have on obtaining benefits from biogas technology compared to other known technologies play a positive role in the adoption decision. A strong preference exists among the studied households in rural Pakistan for biogas technology for cooking based on the perception that the technology is more convenient and efficient in comparison with less efficient biomass technology alternatives. The result supports the findings of previous studies done in different countries, including Pakistan [5,41,49,67,68]. The perception of households that it is easy to operate biogas digesters is another driving factor in their motivation towards deciding to adopt the technology. This assumption is in line with the theoretical basis of the TAM, which assumes that a technology's ease of use has a strong positive effect on people forming positive behavior towards the use of that technology [21]. Another important driver in the adoption process is the people's trust in technology. If people perceive that they have the available infrastructure, technical support, resources, and skills, they are then inclined toward confirmation/adoption by trusting on the reliability and safety of the biogas technology [69,70]. The results indicate that compatibility, efficiency, effectiveness, and convenience are the motivating properties that potential adopters look for when they decide to adopt biogas technology.

Apart from driving factors, perceptions about cost and risk are found to be the inhibiting factors in this decision process. Our study reveals that the perception of technology being pricy and risky reduces the propensity of potential adopters toward the adoption of the technology. This underscores the need for manufacturers reducing the cost and risks of biogas technology [71]. In other countries, such as China and India, the same-sized biogas facility is available with less cost [72]. Along with price comparison with other alternatives, household perceptions about financial, safety, and time risk hinder them from adopting the technology. Although empirically, we found little effect of risk perceptions, our model shows how these perceptions still negatively affect the adoption decision. Therefore, biogas digester manufacturers need to reduce the risks by employing mitigating strategies, such as improving the design for gas leakages and maintaining gas supply despite ambient temperature fluctuations, which are the major concerns of potential adopters [73]. Explaining to potential adopters the costs and risks, as well as advantages compared to other technologies, could contribute to reducing the perceived costs and risks related to the technology.

A key measure of success of biogas technology is the initial adoption, but long-term benefits are reaped only when adopters continue using and experiencing the benefits, as well as reinforcing their intention to continue using the technology. With regards to households having the intention to continue using biogas technology, all proposed hypotheses of the ECM model were validated by the empirical model used in this study, except hypothesis path H8, which states that the perceived usefulness of biogas cooking fuel has a positive effect on satisfaction. Like previous studies, results of hypothesis path H7 show that adoption (confirmation) exerts a positive strong effect on the satisfaction of the users with the technology. This means that meeting the users' pre-adoption expectations about biogas technology is decisive for a high or low satisfaction level. However, the perception on the usefulness of technology in our study turns out to have no direct effect on the continuation, while perception on the usefulness of technology in this study turns out to have a direct effect on the continuation. This observation is unlike the ECM hypothesis. Moreover, we found no link between usefulness perception and satisfaction of the household. One explanation for this is that the users are already familiar with the other benefits of the technology and that they give higher importance to the benefits experienced in the past. Satisfaction with technology leads them to continue choosing technology. Lastly, satisfaction emerges as an important component in the intention to continue the use of the technology. For long-term use of technology, it is more decisive that users are consistent with their previous decision. The users are satisfied because the technology meets their expectations and because they formed positive perceptions about the usefulness of the technology, which overall strengthened their decision to continue the use of the biogas facility.

6. Conclusions and Implications of the Study

The study developed an integrated model for simultaneously analyzing the adoption and continuation of biogas cooking fuel technology in the context of rural Pakistan. The empirical findings confirm the validity of the proposed analytical model. For the adoption of the technology, the study analyzed users' positive and negative perceptions on biogas technology against the subjective beliefs of the households. Users' pre-adoption beliefs about benefits and cost determine the adoption of the technology. The monetary aspects of cost savings, investment, operating cost maintenance cost, as well as the non-monetary aspects of comfort, saved time, compatibility, and convenience, are crucial in the studied adoption process. Moreover, obstacles are as important as the facilitating factors in this adoption process. It is evident that the high cost and risks involved in the uptake of biogas technology slow down the process of adoption [74,75]. One way for addressing this issue is to provide more training to users and thus minimize the risk of incorrect operation and improve the performance and operational safety of the biogas digesters. To reduce financial risk, easy loan schemes and financial support from private institutions can make the initial investment manageable for the users with a limited budget. Evidence suggests that addressing non-monetary aspects explicitly facilitates adoption and ensures continued use. This can be improved by focusing on the comfort of operation, highlighting the timesaving features of biogas digesters, and offering follow-up services for greater convenience.

Post-adoption perceptions concerning the usefulness of the technology determine the satisfaction level of the users, which is an important determinant in users' intention to continue using biogas technology. For a sustainable continuation of biogas technology, the technology's usefulness when compared to traditional cooking fuel technologies enhances the probability of users continuing the usage after initial adoption. The satisfaction of users and their willingness to continue using the technology will likely increase if biogas technology meets their efficiency expectations better than other traditional cooking fuels. One suggestion is to have proactive marketing and communication that focuses on the usefulness and efficiency of biogas technology without ignoring the limitations. Raising awareness and adapting beliefs to the realities of biogas technology is necessary for enhancing the adoption and acceptance of the technology.

The study contributes to the theory and model development by combining adoption and continuation intention in one model for analysis based on pre- and post-adoption expectations and performance perceptions. The model is suitable for describing the adoption and continuation processes of other technologies in various contexts. The study also contributes to the literature on renewable energy development, specifically in South Asian emerging economies where more effort is desirable for developing societal and local conditions in rural areas that are conducive for the adoption of these innovative technologies. From the managerial perspective, the study gives an indication for policymakers and manufacturers to think beyond the general economic conditions and includes the expectations and non-monetary aspects of the end-users in their agendas and policy formulations. Moreover, the proven relationship between satisfaction and intention to continue using biogas technology gives an indication to the service providers for continuing their investments in maintaining or increasing the satisfaction level of the end-users, thus securing the long-term use of the technology. Service providers should devise strategies for enhancing the satisfaction level among existing users by meeting their specific expectations. This will not only retain the existing users, but these satisfied customers can provide an effective conduit to bring in new users via word of mouth.

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Appendix A

Table A1. Items and source of scales.

Construct	Items	Description	Sources
Price benefits	PB1	I believe biogas technology leads to a better and clean environment	Park and Ohm (2014) [44]
	PB2	I believe biogas technology helps in saving expenditures	
	PB3	I believe biogas technology helps in saving cooking time	
Perceived ease of use	EU1	Learning how to use biogas digesters is easy for me	Davis et al. (1989); Venkatesh et al. (2011) [21,57]
	EU2	Operation of biogas digesters is clear and understandable	
	EU3	I find biogas digesters easy to use	
Perceived trust	PT1	Biogas technology is more reliable than other energy technologies	Kim (2014); Park and Ohm (2014) [44,56]
	PT2	Biogas technology is more trustworthy than other energy technologies	
	PT3	Biogas technology is more secure than other energy technologies	

Table A1. *Cont.*

Construct	Items	Description	Sources
Perceived cost	PV1	Biogas digesters equipment cost is generally expensive	Park and Ohm (2014); Venkatesh et al. (2011) [44,57]
	PV2	The maintenance cost of using biogas is expensive	
	PV3	It takes a considerable amount of effort and cost to operate biogas digesters	
Perceived risk	PR1	I am afraid of suffering financial losses when using biogas technology	Park and Ohm (2014) [44]
	PR2	Biogas technology is not safe	
	PR3	I worry about whether biogas technology will perform as well as traditional fuels	
Perceived usefulness	US1	Using biogas digesters increases my efficiency at home (while cooking)	Venkatesh et al. (2011) [57]
	US2	Using biogas digesters helps me to perform the task conveniently (i.e., cooking)	
	US3	Using biogas digesters helps me to reduce my energy consumption at home	
Satisfaction	S1	How do you feel about your overall experience of biogas technology use;Very dissatisfied/very satisfied	Bhattacherjee, 2001 [20]
	S2	Very displeased/very pleased	
	S3	Very frustrated/very contented	
	S4	Absolutely terrible/absolutely delighted	
Confirmation	C1	My experience with biogas technology was better than what I expected	
	C2	The service level provided by biogas technology was better than what I expected	
	C3	Overall, most of my expectations from using biogas technology were confirmed	
Continued intention	CI1	I plan to continue using biogas rather than discontinue its use	
	CI2	I intend to continue using biogas technology than use any alternative means (traditional technologies)	
	CI3	If I could, I would like to discontinue my use of biogas technology in the future	

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