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Modelling household's intentions to adopt hybrid power system in Ghana

Eric Koranteng[a], Francis Kwesi Bondinuba[b,c] and Gylbet Camynta-Baezie[d]

[a]Institute of Distance Learning, Kwame Nkrumah University of Science and Technology, Ghana; [b]The Urban Institute, School of Energy, Geoscience, Infrastructure and Society, Heriot-Watt University, Edinburgh, Scotland, UK; [c]Department of Building Technology, Faculty of Built and Natural Environment, Kumasi Technical University, Ghana; [d]Department of Planning, Kwame Nkrumah University of Science and Technology, Ghana

ABSTRACT
The study investigates the factors influencing households' intentions to adopt hybrid power systems in Ghana. Data was collected from 290 households in the Amasaman district using a quantitative survey design. Factors affecting households' intentions included knowledge of the technology, perceived usefulness and benefits, perceived risks and costs, willingness to adopt, age, gender, educational level, religion, household size, type of residence, membership size and energy expenditure. Barriers to adoption included high upfront costs, limited availability of hybrid power systems and inadequate infrastructure. The model predicted that only 44% of households would be willing and intend to use hybrid power systems. The study highlights the role of socioeconomic factors, environmental consciousness and barriers in Ghana's transition to a low-carbon economy. It suggests policymakers and stakeholders should ensure hybrid power systems' financial and social acceptability. Limitations include focusing on intentions rather than adoption rates, potential response bias and measurement error. Recommendations include targeted policies, financial incentives, infrastructure development and awareness campaigns. The study contributes to Ghana's sustainable development goals by promoting reliable, clean electricity, particularly in rural areas with limited grid connectivity, aligning with the United Nations Sustainable Development Goals.

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1. Introduction

Energy consumption has surged globally due to socio-economic progress, technological advancements and population growth. This demand affects all sectors, including transportation, residential, commercial and industrial. The International Energy Outlook (IEO, 2021) predicts a 50% increase in global household energy consumption between 2010 and 2040. However, according to Colelli et al. (2022), energy usage contributes to environmental degradation, including climate change, air pollution, soil contamination and rising sea levels. The International Energy Agency (IEA, 2021) reports increased efforts to produce, transport and consume renewable energy. In this regard, renewable energy sources are increasingly being adopted due to rising fossil fuel costs and the need to reduce carbon dioxide emissions United Nations (UN, 2024). According to the World Economic Forum (WEF, 2021), they can contribute to sustainable development goals, including energy access, security, climate change mitigation and environmental and health issues (Strokal et al., 2021). The World Economic Forum (WEF, 2024) and the World Bank (WB, 2023) further highlight the growing global interest in renewable energy systems due to climate change

CONTACT Francis Kwesi Bondinuba francis.kbondinuba@kstu.edu.gh Department of Building Technology, Faculty of Built and Natural Environment, Kumasi Technical University, Ghana.

and fossil fuel depletion. In this regard, the United Kingdom plans to reduce carbon emissions by 60% by 2050, with renewable energy making up 20% of total power generation by 2025 (Gov. UK, 2020).

Ghana, a West African nation, is experiencing rapid economic growth, which has led to increased energy demands and reliance on traditional fossil fuels, particularly in households. Around 70% of Ghanaians rely on biomass for cooking and heating, causing environmental degradation and health issues (Abdul-Wakeel Karakara & Dasmani, 2019). The country's electricity generation relies heavily on fossil fuels, making it susceptible to price fluctuations and supply disruptions (Nyasapoh et al., 2023). According to Quaicoe (2022), the government has set ambitious targets of 10% renewable energy penetration by 2030 to address these challenges. Like many developing countries, Ghana faces unique challenges in meeting energy demands while promoting sustainable development. However, the country's favourable climate makes it well-suited for harnessing renewable energy sources like solar and wind. Hybrid power systems, which combine renewable and traditional energy sources, offer a potential solution to these issues.

Hybrid systems are essential to Ghana's electricity infrastructure and can provide reliable and sustainable power in areas with limited grid connectivity. These systems combine renewable and conventional energy sources to meet the energy demands of communities and businesses. They are crucial for off-grid electrification projects in rural areas and mini-grids (Awopone, 2021), providing additional power during peak demand periods. Hybrid systems also enhance grid stability and reliability by providing additional power during peak demand periods and compensating for fluctuations in renewable energy generation (Mensah & McWilson, 2021). They also facilitate renewable energy integration, reducing dependence on fossil fuels and reducing costs (Odoi-Yorke et al., 2022). Hybrid systems contribute to sustainable development, cost savings and environmental benefits.

Despite their benefits, the adoption and uptake of hybrid power systems among Ghanaian households are limited. Again, notwithstanding the few studies exploring off-grid hybrid energy systems (Awopone, 2021), hybrid solar-biogas systems (Agyenim et al., 2020), solar home systems (Mensah & McWilson, 2021) and solar PV/biogas hybrid energy systems (Antwi et al., 2017; Odoi-Yorke et al., 2022), none focus on the adoption and uptake of hybrid power systems among Ghanaian households. This study aims to understand and model the factors influencing households' intentions to adopt hybrid power systems. It is, therefore, argued that raising awareness about environmental preservation can encourage the adoption of renewable technologies, influencing households' intentions to adopt hybrid power systems. The article is structured into six main sections, with section one being an introduction that sets the background of the study. Section two synthesises the literature on the types of hybrid power systems and their effects on family livelihoods in Ghana. Section three outlines the research approach adopted. In section four, the data are analysed and discussed and study implications for policy research and practice are stated in section five. Section six contains the conclusion of the study.

2. Types of hybrid power systems and their effects on family livelihood in Ghana

Researchers have identified hybrid power systems, such as PV/battery/diesel and PV/diesel/grid, as suitable options for small and medium-sized enterprises (SMEs) in Ghana, offering sustainable energy for businesses (Odoi-Yorke et al., 2022) as shown in Table 1. Mohammed et al. (2020) also put forward that integrating solar PV systems with biogas plants has been feasible and cost-effective, providing communities with a more secure and efficient energy supply. Standalone solar PV/battery systems are sometimes preferred for powering off-grid telecommunication sites due to their lower costs and reduced greenhouse gas emissions compared to diesel generators, as stated by Issahaku and Kemausuor (2022). Additionally, solar PV/biogas/battery hybrid systems can provide cost-effective electricity for remote communities in Ghana, reducing emissions and improving access to electricity (Odoi-Yorke et al., 2022). Hybrid power systems combining solar PV, wind and diesel generators have also been considered environmentally friendly and cost-effective for electrification in remote areas (El Bakkush et al., 2015; Tay et al., 2022).

Solar-diesel hybrid systems combine solar energy with a diesel generator, reducing reliance on expensive diesel fuel. Wind-diesel hybrid systems combine wind energy with a diesel generator, allowing families to save money and invest in other essential expenses. Solar-wind hybrid systems combine solar and

Table 1. Typology of hybrid power systems.

	Types	Description	Source
1	PV/battery/diesel	PV or battery or diesel	Odoi-Yorke et al. (2022)
2	PV/diesel/grid	PV or diesel or grid	Odoi-Yorke et al. (2022)
3	Solar PV systems with biogas plants	solar PV systems with biogas plants	Mohammed et al. (2020)
4	Standalone solar PV/battery systems	solar PV or battery systems	Issahaku and Kemausuor (2022)
5	Solar PV/biogas/battery hybrid systems	Combination of solar PV with biogas or battery	Issahaku and Kemausuor (2022)
6	Solar PV, wind and diesel generators hybrids	Combination of solar PV, wind and diesel generators	Tay et al. (2022)
7	Solar-diesel hybrid systems	Combination of solar energy with a diesel generator	Lee et al. (2003)
8	Wind-diesel hybrid systems	Combination wind energy with a diesel generator,	Jaradat and Mashaqba (2014)
9	Solar-wind hybrid systems	Combination of solar and wind energy	Flett et al. (2004)
10	Biomass-diesel hybrid systems	use of biomass, such as agricultural waste with a diesel generator	Brown and Venkatesh (2005)

Authors Construct, 2021.

wind energy, providing a reliable power supply. Biomass-diesel hybrid systems combine biomass, such as agricultural waste or wood chips, with a diesel generator, providing a sustainable and affordable energy source for rural families. These systems can significantly reduce electricity costs, freeing up education, healthcare and business development funds. They can also contribute to a cleaner, more sustainable environment, improving the overall quality of life for families in Ghana.

2.1. Modelling households' intentions to adopt a hybrid power system

In recent years, hybrid power systems have gained popularity as a sustainable and alternative solution for power generation, particularly in developing countries like Ghana, where unreliable grid supply and limited access to electricity in remote areas pose significant challenges. Additionally, hybrid power systems that combine traditional energy sources with renewable energy technologies have become increasingly popular due to the growing concern over climate change and the need to transition to renewable energy sources. These systems effectively reduce greenhouse gas emissions and energy costs while ensuring a reliable power supply. Deploying hybrid power systems in Ghana can contribute to sustainable development and improve the livelihoods of communities. This section examines the factors that impact households' willingness to adopt hybrid power systems in Ghana using the Technology Acceptance Model (TAM) framework.

The TAM is a widely used framework in information systems and technology that predicts individuals' acceptance and usage of technology (Bruner & Kumar, 2005; Flett et al., 2004; Jaradat & Mashaqba, 2014). According to Brown and Venkatesh (2005), psychological factors such as perceived usefulness and ease of use are considered determinants of attitudes towards using a particular technology. Researchers have extended the TAM to include social influence factors, such as subjective norms and social influence. It suggests that individuals' perceptions of social pressure to use technology influence their attitudes and intentions (Dadzie et al., 2018; Flett et al., 2004). Attitudes refer to households' overall assessment of the advantages and disadvantages of adopting hybrid power systems; subjective norms encompass the influence of social networks and societal norms on adoption decisions; and perceived behavioural control represents the ease or difficulty of adopting the technology (Jaradat & Mashaqba, 2014; Lee et al., 2003). The TAM has limitations, including focusing on individual-level factors and excluding organisational-level factors. Future research should explore its cross-cultural applicability to understand technology acceptance behaviour in diverse cultural contexts.

The study conceptualised external factors, such as households' characteristics, knowledge and awareness of hybrid power systems, that will influence the drivers and inhibitors, as shown in Figure 1. These drivers and inhibitors will impact households' attitudes towards hybrid systems and determine their willingness to adopt them. Therefore, willingness becomes a vital force influencing households' intentions to adopt hybrid power systems. The study defines external factors as households' characteristics, knowledge and awareness of hybrid power systems. Understanding hybrid power systems as renewable energy sources that can be used independently or jointly with the national grid will drive knowledge and awareness. They are also considered inexhaustible sources. Social factors such as norms, cultural values and

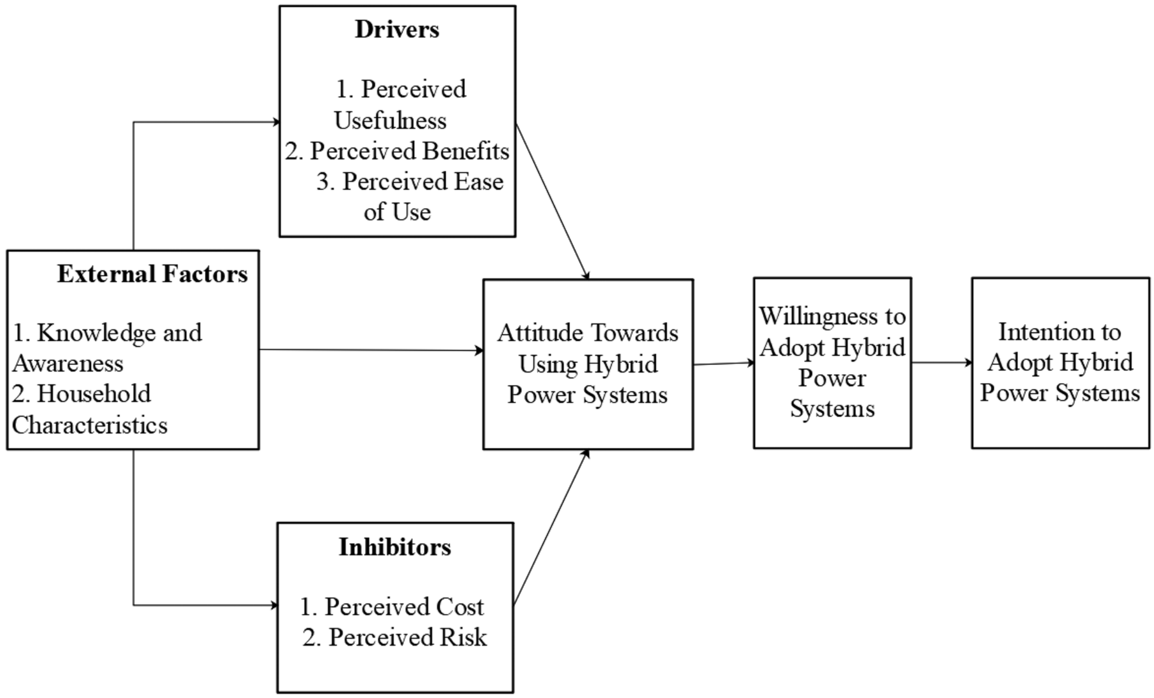

Figure 1. Conceptual framework. Authors', Construct, 2021.

peers influence households' intentions to adopt hybrid power systems. Hafezi and Alipour (2020) also suggest that perceiving prestigious, modern symbolism and information dissemination through social networks positively impacts adoption rates. Ngeno's (2014) study on Kenyan families' adoption of solar energy technologies reveals that income, knowledge and backup power sources influence adoption, with education playing a crucial role. However, the study could be criticised for its insufficient design, data analysis and generalizability. The study's sample size of 300 families is unjustified, and the conceptual framework and variables are unclear.

Their perceived usefulness and benefits drive households to adopt hybrid power systems. According to Feng's (2012) study on renewable energy adoption and intention, factors such as perceived usefulness, subjective norm, compatibility and ease of use can help predict future usage and aid marketing and advertising efforts. However, the methodology of this study is unclear, making it difficult to evaluate the reliability and validity of the findings. The study's implications for marketing and advertising are logical but require more concrete recommendations. In this regard, households consider the hybrid system useful if it makes their lives easier, is simple to use, improves job quality and standard of living, and is reliable. They will also perceive it as beneficial if it improves their quality of life, reduces energy expenditure, increases disposable income, contributes to energy security and creates a mentality of self-sustainability. Hybrid power systems offer environmental benefits, such as reduced carbon emissions and reliance on fossil fuels (Muljadi & McKenna, 2001). Gheisarnejad et al. (2023) argued that awareness of climate change and environmental education drive adoption, promoting positive attitudes towards renewable energy sources. Research by The Energy Saving Trust (2007) and Caird et al. (2008) found that households' perceptions of cost impact their readiness to embrace renewable energy (RE). Consumers may reduce their purchase intentions or delay them until a suitable price is set, as the initial costs of installing and maintaining technology can be substantial (Zhang et al., 2018).

Conversely, the inhibitors are the perceived risks and costs of the hybrid power system. Households may perceive risks when they realise that their current hybrid power systems are not durable or sustainable or if the configurations are unstable. Wang et al. (2008) also claimed that perceived advantages, costs and benefits influence hybrid energy adoption. Thus, high-risk or expensive products may deter adoption decisions (Ross & Feng, 2008). However, their study lacks specificity, has an unclear methodology and presents results insufficiently. Perceived risk refers to the uncertainty and potential drawbacks of acquiring a product or service, often causing consumers to fear the rapid obsolescence and devaluation of high-tech devices. They will perceive costs as high if the price is beyond their budget, servicing and maintenance charges are expensive or the overall cost of the hybrid power system adoption and installation is expensive. Economic factors play a crucial role in adopting hybrid power systems. Thus, the initial investment, ongoing maintenance and operational costs can be significant household inhibitors or barriers. Studies have shown that financial incentives, such as subsidies, grants and tax rebates, can positively influence households to adopt hybrid power systems (Kgopana & Popoola, 2023; Zhao, 2023). Moreover, the availability of financing options and pay-as-you-go models can make these systems more accessible to households with limited financial resources (Muloo et al., 2023). Households decide to adopt the system based on how useful they anticipate it to be and their willingness to use it. For instance, hybrid power systems' reliability, performance, affordability and maintenance-friendliness are crucial factors in household adoption. Advancements in battery storage and smart energy management systems enhance their appeal. Government policies, regulatory frameworks and institutional support influence adoption, including financial incentives and simplified administrative procedures.

3. Research method

This study used a quantitative survey design to model households' intentions to adopt hybrid power systems. 290 households in the Amasaman district provided data through a self-administered questionnaire, encompassing demographic information, energy use behaviour, attitudes towards renewable energy and intentions to adopt hybrid power systems; however, only 266 responses were considered usable due to the elimination of questionnaires with missing information as shown in Table 2. Amasaman district in Ghana is a prime location for a study on households' intentions to adopt hybrid power systems. The densely populated area, with a mix of urban and peri-urban households, offers a representative sample for understanding the adoption of hybrid power systems. The district's intermittent power supply and unreliable electricity make it an ideal location for studying hybrid power systems. Ghana's target to increase its renewable energy share makes Amasaman a suitable case study. Understanding these factors can help develop targeted strategies for promoting sustainable energy solutions.

Table 2. Descriptive statistics of respondents.

Demographic variables	Subgroups	Frequency ($N = 266$)	Percentage (100%)
Age	25–30	40	15.0
	31–35	106	39.8
	36–40	99	37.2
	41–45	19	7.1
	>45	2	0.8
Gender	Male	158	59.4
	Female	108	40.6
Educational level	Diploma/HND	40	15.0
	Bachelor's Degree	65	24.4
	Master's Degree	30	11.3
	PhD	5	1.9
	No formal Education	21	7.9
	WASSCE cert	86	32.3
	BECE cert	19	7.1
Type of residence	Self-owned	63	23.7
	Rented	170	63.9
	Care Taker	33	12.4
Religion	Christian	136	51.1
	Muslim	130	48.9
Size of household	Single room	12	4.5
	Chamber and Hall	26	9.8
	1-room self-contain	39	14.7
	Chamber &Hall self contain	78	29.3
	2 bed room	56	21.1
	3 bed room	40	15.0
	4 bed room	10	3.8
	5 bed room	5	1.9

Source: Field data, 2021.

We distributed the questionnaire through various methods, including online platforms and in-person distribution. The multistage random sampling approach selected a random sample of households from various sources, ensuring demographic diversity. The questionnaire was designed based on a literature review and previous studies on adopting renewable energy. It consisted of multiple sections and used a Likert scale to measure attitudes and intentions. We pilot-tested it for clarity, validity and reliability. The data analysis used descriptive and inferential statistical techniques, summarising demographic characteristics, energy use behaviour and attitudes towards renewable energy. We considered the ethical implications and provided participants with informed consent forms while following relevant guidelines.

4. Presentation and discussion of results

4.1. Demographic characteristics of respondents

This section presents the participants' demographic analysis. The results from the descriptivestatistics showed a total of 266 participants as shown in Table 2. Regarding age, the majority of the respondents were between 31-35 years, representing a percentage of (39.80%). This was closely followed by respondents between 36 and 40 years, who also represented 37.2% of the study population. Respondents with ages greater than 45 years had the least representation of 0.8%. For respondents' gender, females constituted 40.6% of the sample size and males dominated with a percentage of 59.4%. Concerning educational qualification, respondents with WASSCE certificates dominated with a corresponding percentage of 32.3%. This was closely followed by respondents with a bachelor's degree representing 24.4%, then followed by Diploma and HND certificates constituting 15.0%. Respondents with PhD had the least representation of 1.9%. Considering the type of residence among respondents, it was found out that, majority of the participants lived in rented households. This is represented by 63.9% of the study population. This was followed by respondents who have self-owned households which represents 23.7%. Respondents who are caretakers of households had the least representation ($N = 33$). In terms of religion, Christians dominated ($N = 136$) representing 51.1% of the study population. The remaining were Muslims ($N = 130$) who also represented 48.9%.

4.2. Factors that influence the adoption of hybrid power systems among households

4.2.1. Knowledge and awareness

Taken together the responses on the knowledge and awareness about hybrid systems, 'Renewable energy sources are inexhaustible source of energy' had the highest average score (mean = 3.91; $SD = 0.83$) while the least item score came from 'Hybrid power systems can be used independent of national grid' with a mean of 2.91 and *SD* of 1.19. All the indicators on knowledge and awareness had an average score higher than 3.60 which was beyond the median of 3. This signifies that averagely respondents have relatively high knowledge and awareness about hybrid power systems.

The study revealed that the level of knowledge and awareness of solar technology, level of income of households and availability of substitute power source influence the adoption of domestic solar technology as shown in Table 3. The outcome of this survey suggests respondents are likely to adopt since education provides adopting agents with the tools to understand and be acquainted with the direct and indirect advantages of adopting hybrid energy. These findings support Ngeno (2014) study among

Table 3. Descriptive statistics of knowledge and awareness.

Indicators	Mean	Std. deviation
Renewable energy sources are inexhaustible sources of energy	3.91	0.83
Hybrid power systems incorporate one or more renewable energy sources	3.89	0.74
Hybrid power systems can be used independently of the national grid	2.91	1.19
Hybrid power systems can be used jointly with the national grid	3.86	0.94
OVERALL	3.64	0.93

Source: Field data, 2021.

households in Kenya on the factors affecting the adoption of solar power technology for domestic power usage.

4.2.2. Perceived usefulness

Taken together the responses on perceived usefulness of hybrid power systems, 'I will adopt if it is reliable for all uses' had the highest average score (mean = 3.98; *SD* = 0.75) while the least item score came from 'I will adopt If it improves job quality and standard of living' with a mean of 3.82 and *SD* of 0.72. All the indicators on perceived usefulness had an average score higher than 3.80 which was beyond the median of 3 as shown in Table 4. This signifies that averagely respondents agree that hybrid power systems are useful hence may have an influence on the adoption. The outcome of this investigation confirms with results from a study conducted by Bergek and Mignon (2017) who concluded that perceived usefulness is one of the major factors influencing the adoption of renewable energy technologies among the sampled respondents.

4.2.3. Perceived benefits

The use of the hybrid system will contribute to my energy security, autonomy and freedom of choice had the highest average score (mean = 3.22; *SD* = 0.95) while the least item score came from 'The adoption of the hybrid system will create a mentality of self-sustainability for the building' with a mean of 2.76 and *SD* of 0.88. All the indicators on perceived had an average score lower than 2.90 which was below the median of 3 as shown in Table 5. This signifies that averagely respondents disagree that hybrid power systems are beneficial for adoption in households. Wang et al. (2008) posits that a consumer weighs the benefits against the cost of adoption and if the perceived benefit outweighs the perceived cost, consumers are more likely to adopt the product or service. The outcome of this study suggests the benefits of adopting hybrid power systems is not compelling enough.

4.2.4. Perceived risk

Taken together the responses on perceived risk of hybrid power systems, 'I believe that the setups or configurations of the current hybrid power systems are not yet stable' had the highest average score (mean = 3.21; *SD* = 0.97) while the least item score came from 'I believe that the current hybrid power systems are not sustainable' with a mean of 3.20 and *SD* of 1.0. All the indicators on perceived risk had an average score higher than 3.20 which was beyond the median of 3. This signifies that averagely respondents agree that hybrid power systems are risky to adopt as shown in Table 6. If consumers perceive the product offered to be of high risk or high expense in comparison to the benefits, they may defer their adoption decision or reject buying it outright. Sarin et al. (2003) argued that consumers perceive the purchase of new high-tech products to be risky due to products and industries exhibiting pervasive technological and market doubts.

Table 4. Descriptive statistics of perceived usefulness.

Indicators	Mean	Std. deviation
Makes life easier for me	3.87	0.71
Simple to use	3.89	0.67
Improves job quality and standard of living	3.82	0.72
Reliable for all uses	3.98	0.75
OVERALL	3.89	0.71

Source: Field data, 2021.

Table 5. Descriptive statistics of perceived benefits.

Indicators	Mean	Std. deviation
Improve quality of life	2.69	0.82
Reduce energy expenditure	2.76	0.84
Increase disposable income	2.76	0.85
Contribute to energy security and freedom of choice	3.22	1.02
Create a mentality of self-sustainability	2.76	0.88
OVERALL	2.84	0.88

Source: Field data, 2021.

Table 6. Descriptive statistics of perceived risk.

Indicators	Mean	Std. deviation
Current hybrid power systems are not durable	3.21	1.02
Current hybrid power systems are not sustainable	3.20	1.00
Configurations of the current hybrid power systems are not stable	3.21	0.97
OVERALL	3.21	1.00

Source: Field data, 2021.

Table 7. Descriptive statistics of perceived cost.

Indicators	Mean	Std. deviation
Price of hybrid power systems is beyond budget	3.77	0.98
Servicing and maintenance charge for hybrid power systems is expensive	4.03	0.73
Total cost of hybrid power systems adoption and installation is expensive	3.97	0.73
OVERALL	3.92	0.81

Source: Field data, 2021.

Table 8. Descriptive statistics of willingness to adopt.

Indicators	Mean	Std. deviation
Confident with the idea of adopting the hybrid power system	3.04	1.18
Easy1to adopt the hybrid power system	2.87	1.05
OVERALL	2.96	1.12

Source: Field data, 2021.

Table 9. Descriptive statistics of intention to adopt.

Indicators	Mean	Std. deviation
Intend to use the hybrid system	2.62	0.84
Predict will use the hybrid system	2.71	0.97
OVERALL	2.67	0.91

Source: Field data, 2021.

4.2.5. Perceived cost

Taken together the responses on perceived expense of hybrid power systems, 'I believe that the current servicing and maintenance charge for hybrid power systems is expensive' had the highest average score (mean = 4.03; *SD* = 0.73) while the least item score came from 'I believe that the current price of adopting hybrid power systems is beyond my budget' with a mean of 3.77 and *SD* of 0.98. All the indicators on perceived expense had an average score higher than 3.90 which was beyond the median of 3 as shown in Table 7. This signifies that averagely respondents agree that adopting hybrid power systems is expensive. When a consumer intends to adopt RE, he or she will conduct a cost-benefit evaluation before making a purchase decision. If they perceive that the monetary adoption cost (expenses) of the product outweighs its benefits, the purchase intention may be reduced or postponed until the price is perceived as acceptable.

4.2.6. Willingness to adopt

Taken together the responses on the willingness to adopt hybrid power systems, 'I feel confident with the idea of adopting the hybrid power system' had the highest average score (mean = 3.04; *SD* = 1.18) while the least item score came from 'I think it will be easy forme to adopt the hybrid power system' with a mean of 2.87 and *SD* of 1.05 as shown in Table 8. Both indicators on willingness to adopt had an average score below the median of 3. This signifies that averagely respondents reported disagreement to willingly adopt hybrid power systems.

4.2.7. Intention to adopt

Taken together the responses on the intention to adopt hybrid power systems, 'I predict that I will use the hybrid system' had the highest average score (mean = 2.71; *SD* = 0.97) while the least item score came from 'I intend to use the hybrid system' with a mean of 2.62 and *SD* of 0.84. Both indicators on intention to adopt had an average score lower than 2.70 which is below the median of 3 as shown in Table 9. This signifies that averagely respondents disagree to any intention of adopting hybrid power systems.

4.3. Multiple regression model

A multiple regression model was built to evaluate the factors that has influenced adoption of hybrid power systems among households in the Amasaman District. In this study, the dependent variable of the model is the intention to adopt hybrid power system by household. The independent variables include knowledge and awareness, perceived usefulness, perceived benefits, perceived risks, perceived expenses, willingness to adopt, age, gender, educational level, religion, household size, type of residence, membership size and amount spent on energy. To validate factors or attributes that significantly influences the intention to adopt hybrid power systems, the backward elimination technique was adopted. It is used to remove those features or variables that do not have a significant effect on the dependent variable or prediction of output. Independent variables or factors in the model with corresponding *P*-values less than or equal to the alpha or significance level or.05 is justified as having a significant effect while factors with corresponding *P*-values greater than.05 are termed as insignificant.

The multiple regression equation is as follows:

$$\begin{aligned} IA = Bo + KAB_1 + PUB_2 + PBB_3 + PRB_4 + PEB_5 + WA_6 + GB_7 \\ + AB_8 + ELB_9 + RTB_{10} + HSB_{11} + MSB_{12} + ASB_{13} + RB_{14} \end{aligned} \quad (1)$$

where IA is the dependent variable of the equation. Bo is a constant of the equation B_1, B_2, B_3, B_4, B_5, B_6, B_7, B_8, B_9, B_{10}, $B_{11,}$ B_{12}, $B_{13,}$ $B_{14,}$ are coefficients of the independent variables. KA, PU, PB, PR, PE, WA, G, A, EL, RT, HS, MS, AS and R are the independent variables of the equation.

Description of Variables

IA- Intention to adopt hybrid power systems
KA- Knowledge and awareness of hybrid power systems
PU- Perceived usefulness of hybrid power systems
PB- Perceived benefits of hybrid power systems
PR- Perceived risk of hybrid power systems
PE- Perceived expense of hybrid power systems
WA- Willingness to adopt hybrid power systems
G- Gender of respondent
A-Age of respondent
EL- Education level of respondent
RT- Type of residence
HS- Household size
MS- Membership size
AS- Amount spent on energy
R- Religion

4.4. Model summary

On the 11th iteration of the backward elimination technique, the regression model was reduced to only four independent variables which have significant effect on the dependent variable. These independent variables include; willingness to adopt hybrid power system, age, membership size and amount spent on energy by respondent. These independent variables include; willingness to adopt hybrid power system, age, membership size and amount spent on energy by respondent. The model and its coefficient is provided in the Table 10.

Regression Model is presented below and the results are shown in Table 11.

Table 10. Model coefficients.

	Model	Unstandardised coefficients B	Std. error	*P* value
11	(Constant)	0.882	0.177	.000
	WA	0.448	0.039	.000
	A	0.107	0.055	.054
	MS	−0.079	0.035	.023
	AS	0.007	0.002	.000

Source: Field data, 2021.

Table 11. ANOVA.

	Model	Sum of squares	*df*	Mean square	*F*	*P* value
11	Regression	77.179	4	19.295	47.605	0.000
	Residual	105.785	261	0.405		
	Total	182.963	265			

Source: Field data, 2021.

Table 12. Validation of model.

Model summary				
Model	*R*	*R* square	Adjusted *R* square	Std. error of the estimate
11	0.649	0.422	0.413	0.63664

Source: Field data, 2021.

$$\begin{aligned}\text{Intention to Adopt} = 0.882 &+ (0.448 \times \text{Willingness to adopt}) \\ &+ (0.107 \times \text{Age})(0.079 \times \text{Membership size}) \\ &+ (0.007 \times \text{Amount on energy})\end{aligned} \quad (2).$$

According the ANOVA table, the computed test statistic ($F = 47.605$) is significant since the computed P value is less than the alpha level (thus, P value $= .000 < .05$). This implies that each independent variable that affects or influences the dependent variable varies significantly from each other in the regression model. The R Square value of 0.422 as shown in Table 12 depicts that the final model is near a moderate fit with the independent variables explaining about 42% of the variability in the dependent variable 'intention to adopt hybrid power system'.

4.5. Discussion of results

The study found several factors influencing Ghana's household intention to adopt hybrid power systems, including income level, education, awareness and environmental consciousness. These findings align with previous technology adoption research (Ngeno's, 2014; Lee et al., 2003; Jaradat & Mashaqba, 2014; Flett et al., 2004; Bruner & Kumar, 2005; Brown & Venkatesh, 2005), suggesting that socioeconomic factors are crucial in decision-making. Higher income levels were positively associated with adopting hybrid power systems, indicating that affordability remains a significant inhibitor for many households in Ghana. Similarly, education was found to positively influence adoption intentions, suggesting that knowledge and awareness of the benefits of hybrid power systems are important drivers. Furthermore, the study revealed that environmental consciousness is crucial in shaping households' intentions to adopt hybrid power systems. This finding is tied with Effendi et al. (2024), who highlight the potential for leveraging environmental concerns as a motivation for promoting sustainable energy solutions. Policies and initiatives that emphasise the environmental benefits of hybrid power systems could effectively encourage adoption among households in Ghana.

The study also identified several inhibitors to adopting hybrid power systems in Ghana. These inhibitors include high upfront costs, lack of access to financing, limited availability of hybrid power systems in the market and inadequate infrastructure. The high upfront costs of hybrid power systems were consistently mentioned by Ngeno's (2014; Azizi et al., 2016) as a major obstacle, indicating the need for financial incentives and support mechanisms to make these systems more affordable for households.

Additionally, the limited availability of hybrid power systems in the market and inadequate infrastructure pose significant challenges to their adoption. Addressing these barriers requires collaboration between policymakers, energy providers and other stakeholders to ensure the availability and accessibility of hybrid power systems.

5. Limitations

The study on Ghana's adoption of hybrid power systems has limitations, including not assessing adoption rates or long-term impacts, being context-specific and potentially subject to response bias and measurement error. The study's focus on households' intentions and social desirability bias may also affect its generalizability. Future research should explore factors influencing hybrid power system adoption, evaluate their impact on energy consumption, cost savings and environmental outcomes and closely monitor adoption. Cross-cultural studies could provide valuable insights into factors influencing hybrid power system adoption in diverse contexts.

6. Conclusion

The study concludes that hybridising renewable energy sources offers efficient and reliable electricity, reducing energy fluctuation and emissions. However, demographic variables, such as willingness to adopt, age, household size and energy usage, significantly influence households' intentions to adopt hybrid power systems. The study underscores the need for targeted policies, awareness campaigns and collaboration to promote the widespread adoption of hybrid power systems. The study contributes to the existing literature by developing a model explaining households' intentions to adopt hybrid power systems.

Disclosure statement

No potential conflict of interest was reported by the authors.

About the authors

Eric Koranteng is currently the technical manager at the Dry Processing Unit of Bomart Farms Limited and a final year MSc student at the Institute of Distance Learning, Kwame Nkrumah University of Science and Technology, Ghana.

Francis Kwesi Bondinuba is an Associate Professor at the Department of Building Technology at Kumasi Technical University in Kumasi, Ghana. He is currently a visiting scholar at the Urban Institute, School of Energy, Geoscience, Infrastructure and Society, Heriot-Watt University in Edinburgh, Scotland, UK.

Gylbet Camynta-Baezie is a lecturer at the Department of Planning at the College of Art and Built Environment, KNUST, and an Infrastructure and Management Consultant. He previously served as the Executive Chairman of the State Enterprises Commission, which is responsible for overseeing all state-owned enterprises. Additionally, he has authored a novel called The African Agenda and a self-help book called Licence to Print Money.

ORCID

Francis Kwesi Bondinuba http://orcid.org/0000-0001-6030-4784

References

Abdul-Wakeel Karakara, A., & Dasmani, I. (2019). An econometric analysis of domestic fuel consumption in Ghana: Implications for poverty reduction. *Cogent Social Sciences*, *5*(1), 1–14. https://doi.org/10.1080/23311886.2019.1697499

Agyenim, F. B., Dzamboe, P. D., Mohammed, M., Bawakyillenuo, S., Okrofu, R., Decker, E., Agyemang, V. K., & Nyarko, E. H. (2020). Powering communities using hybrid solar biogas in Ghana, a feasibility study. *Environmental Technology & Innovation*, *19*, 100837. https://doi.org/10.1016/j.eti.2020.100837

Antwi, P., Li, J., Boadi, P. O., Meng, J., Shi, E., Deng, K., & Bondinuba, F. K. (2017). Estimation of biogas and methane yields in an UASB treating potato starch processing wastewater with backpropagation artificial neural network. *Bioresource Technology*, *228*, 106–115. https://doi.org/10.1016/j.biortech.2016.12.045

Awopone, A. K. (2021). Feasibility analysis of off-grid hybrid energy system for rural electrification in northern Ghana. *Cogent Engineering*, *8*(1), 198–523. https://doi.org/10.1080/23311916.2021.1981523

Azizi, M., Rahimi, F., Ray, C. D., Faezipour, M., & Ziaie, M. (2016). A decision model for prioritizing geographic regions for cellulosic renewable energy. *Cogent Business & Management*, *3*(1), 1249233. https://doi.org/10.1080/23311975.2016.1249233

Bergek, A., & Mignon, I. (2017). Motives to adopt renewable electricity technologies: Evidence from Sweden. *Energy Policy*, *106*, 547–559. https://doi.org/10.1016/j.enpol.2017.04.016

Brown, S. A., & Venkatesh, V. (2005). Model of adoption of technology in households: A baseline model test and extension incorporating household life cycle. *MIS Quarterly*, *29*(3), 399. https://doi.org/10.2307/25148690

Bruner, G. C., & Kumar, A. (2005). Explaining consumer acceptance of handheld internet devices. *Journal of Business Research*, *58*(5), 553–558. https://doi.org/10.1016/j.jbusres.2003.08.002

Caird, S., Roy, R., & Herring, H. (2008). Improving the energy performance of UK households: results from surveys of consumer adoption and use of low- and zero-carbon technologies. *Energy Efficiency*, *1*(2), 149–166. https://doi.org/10.1007/s12053-008-9013-y

Colelli, F. P., Emmerling, J., Marangoni, G., Mistry, M. N., & De Cian, E. (2022). Increased energy use for adaptation significantly impacts mitigation pathways. *Nature Communications*, *13*(1), 49–64. https://doi.org/10.1038/s41467-022-32471-1

Dadzie, J., Runeson, G., Ding, G., & Bondinuba, F. K. (2018). Barriers to adoption of sustainable technologies for energy-efficient building upgrade—Semi-structured interviews. *Buildings*, *8*(4), 57. https://doi.org/10.3390/buildings8040057

Energy Saving Trust. (2007). Generating the future: An analysis of policy interventions to achieve widespread microgeneration penetration, commissioned by Department for Business, Enterprise and Regulatory Reform (BERR).

Effendi, P. L., Wirjodirdjo, B., & Rosdaniah, S. I. (2024). Influence factors on sustainable business models for renewable energy supply: Indonesian electricity industry. *Cogent Business & Management*, *11*(1), 229–303. https://doi.org/10.1080/23311975.2023.2293303

El Bakkush, A., Bondinuba, F. K., & Harris, D. J. (2015). Exploring the energy consumption dimensions of a residential building in Tripoli, Libya. *International Journal of Engineering Research and Technology (IJERT)*, *4*(10), 5–10.

Feng, H. Y. (2012). Key factors influencing users' intentions of adopting renewable energy technologies. *Academic Research International*, *2*(2), 156.

Flett, R., Alpass, F., Humphries, S., Massey, C., Morriss, S., & Long, N. (2004). The technology acceptance model and use of technology in New Zealand dairy farming. *Agricultural Systems*, *80*(2), 199–211. https://doi.org/10.1016/j.agsy.2003.08.002

Gheisarnejad, M., Mosayebi, M., Rafiei, M., Boudjadar, J., & Khooban, M. H. (2023). Hybrid power systems for smart marine power grids: Demonstration and case study. In *Electric transportation systems in smart power grids* (pp. 473–492). CRC Press.

Gov. UK. (2020). Energy white paper: Powering our net zero future. https://www.gov.uk/government/publications/energy-white-paper-powering-our-net zero-future

Hafezi, R., & Alipour, M. (2020). Sustainable energy management. In: Leal Filho, W., Azul, A., Brandli, L., Lange Salvia, A., Wall, T. (Eds.), *Affordable and Clean Energy*. *Encyclopedia of the UN Sustainable Development Goals*. Cham: Springer. https://doi.org/10.1007/978-3-319-71057-0_3-1

International Energy Agency (IEA). (2021). Net Zero by 2050: A roadmap for the global energy sector. https://www.iea.org/reports/net-zero-by-2050

International Energy Outlook (IEO). (2021). Analysis & projections. https://www.eia.gov/outlooks/ieo/consumption/sub-topic-03.php

Issahaku, M., & Kemausuor, F. (2022). Techno-economic comparison of standalone solar PV and hybrid power systems for remote outdoor telecommunication sites in northern Ghana. *Ghana Journal of Science, Technology and Development*, *8*(2), 1–23. https://doi.org/10.47881/371.967x

Jaradat, M. I. R. M., & Mashaqba, A. M. A. (2014). Understanding the adoption and usage of mobile payment services by using TAM3. *International Journal of Business Information Systems*, *16*(3), 271. https://doi.org/10.1504/IJBIS.2014.063768

Kgopana, K., & Popoola, O. (2023). Improved utilization of hybrid energy for low-income houses based on energy consumption patterns. *AIMS Energy*, *11*(2), 402–403. https://doi.org/10.3934/energy.2023005

Lee, Y., Kozar, K. A., & Larsen, K. R. (2003). The technology acceptance model: Past, present, and future. *Communications of the Association for Information Systems*, *12*(50), 752-780. https://doi.org/10.17705/1CAIS.01250

Mensah, G., & McWilson, W. K. (2021). The dynamics of households' adoption behaviour of solar home systems (SHSS) in Ashongman estate in the greater Accra region of Ghana. *Ghana Journal of Geography*, *13*(1), 235–259. https://doi.org/10.4314/gjg.v13i1.12

Muljadi, E., & McKenna, H. E. (2001). Power quality issues in a hybrid power system. In *Conference Record of the 2001 IEEE Industry Applications Conference. 36th IAS Annual Meeting (Cat. No. 01CH37248)* (Vol. 2, pp. 773–781.). IEEE.

Muloo, S. M., Kimiti, J. M., Mwinzi, M., & Muthike, G. M. (2023). Social-economic factors influencing the adoption of improved energy technologies in Makueni and Machakos Counties, Kenya. *World Journal of Advanced Research and Reviews*, *18*(1), 269–288.

Ngeno, C. N. (2014). *Factors affecting the adoption of solar power for domestic usage in Kajiado County, Kenya* [Doctoral dissertation]. University of Nairobi.

Nyasapoh, M. A., Debrah, S. K., & Twerefou, D. K. (2023). Long-term electricity generation analysis and policy implications–The case of Ghana. *Cogent Engineering*, *10*(1), 220–996. https://doi.org/10.1080/23311916.2023.2209996

Odoi-Yorke, F., Abaase, S., Zebilila, M., & Atepor, L. (2022). Feasibility analysis of solar PV/biogas hybrid energy system for rural electrification in Ghana. *Cogent Engineering*, *9*(1), 203–376. https://doi.org/10.1080/23311916.2022.2034376

Odoi-Yorke, F., Abofra, N., & Kemausuor, F. (2022). Decision-making approach for evaluating suitable hybrid renewable energy system for SMEs in Ghana. *International Journal of Ambient Energy*, *43*(1), 7513–7530. https://doi.org/10.1080/01430750.2022.2068068

Quaicoe, E. B. (2022). Government targets 10% renewable energy penetration by 2030. https://www.myjoyonline.com/government-targets-10-renewable energy-penetration-by-2030/

Ross, R. S., & Feng, Z. (Eds.) (2008). *China's ascent: Power, security, and the future of international politics*. Cornell University Press.

Sarin, S., Sego, T., & Chanvarasuth, N. (2003). Strategic use of bundling for reducing consumers' perceived risk associated with the purchase of new high-tech product. *Journal of Marketing Theory and Practice*, *11*(3), 71–83. https://doi.org/10.1080/10696679.2003.11658502

Strokal, M., Bai, Z., Franssen, W., Hofstra, N., Koelmans, A. A., Ludwig, F., Ma, L., van Puijenbroek, P., Spanier, J. E., Vermeulen, L. C., & van Vliet, M. T. (2021). Urbanisation: An increasing source of multiple pollutants to rivers in the 21st century. *Urban Sustainability*, *1*(1), 24.

Tay, G., Acakpovi, A., Adjei, P., Aggrey, G. K., Sowah, R., Kofi, D., Afonope, M., & Sulley, M. (2022 July). Optimal Sizing and Techno-economic Analysis of a Hybrid Solar PV/wind/diesel Generator System. In *IOP Conference Series: Earth and Environmental Science*, *1042*(1), 012–014.

The World Bank (WB). (2023). Scaling up to phase down: Financing energy transition in developing countries. https://www.worldbank.org/en/news/press-release/2023/04/20/scaling-up-to-phase down-financing-energy-transition-in-developing-countries

United Nations (UN). (2024). Renewable energy – Powering a safer future. https://www.un.org/en/climatechange/raising-ambition/renewable-energy

Wang, Q., Dacko, S., & Gad, M. (2008). Factors influencing consumers' evaluation and adoption intention of really-new products or services: Prior knowledge, innovativeness and timing of product evaluation. *Advances in Consumer Research*, *35*, 416–422.

World Economic Forum (WEF). (2021). Climate change agenda. https://www.weforum.org/agenda/2021/11/un-global-roadmap-net-zero-2050/

World Economic Forum (WEF). (2024). World economic forum annual meeting in Davos Klosters, Switzerland. https://www.weforum.org/events/world-economic-forum-annual-meeting-2024/

Zhang, J., Adu, D., Fang, Y., Antwi, E. O., & Kyekyeku, S. O. (2018). Renewable energy situation in Ghana and future prospect. *Journal of Clean Energy Technologies*, *6*(4), 284–288. https://doi.org/10.18178/JOCET.2018.6.4.475

Zhao, Z. (2023). Operation simulation and economic analysis of household hybrid PV and BESS systems in the improved TOU mode. *Sustainability*, *15*(11), 8853. https://doi.org/10.3390/su15118853