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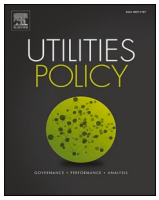

Full-length article

Energy citizenship in northern Ghana: drivers of community engagement in the sustainable energy transitions

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ABSTRACT

This study examines the drivers of community engagement in sustainable energy transitions in Northern Ghana, with a focus on the concept of energy citizenship. Through a survey of 678 residents across selected rural communities, the study examines how awareness, motivation, and perceived benefits influence active participation in renewable energy initiatives, employing the Structural Equation Modeling approach. Key constructs were validated through Confirmatory Factor Analysis, and the relationships were tested using path analysis. Results indicate that community members are motivated by affordability, local economic benefits, and a sense of ownership over energy systems. However, policy awareness showed limited influence on engagement, and infrastructural gaps persist. The study recommends enhanced local engagement strategies and targeted education campaigns to strengthen energy citizenship and promote inclusive energy governance.

1. Introduction

Access to affordable, reliable, and sustainable energy remains one of the most critical challenges confronting developing countries, where large segments of the population continue to experience energy poverty and inadequate access to modern energy services (Pueyo et al., 2016). These deficits hinder socioeconomic development and exacerbate vulnerability to climate change, restricting opportunities for education, healthcare delivery, industrialization, and overall quality of life (Momodu et al., 2022). In Sub-Saharan Africa, the situation is particularly severe, as rural communities often rely on traditional biomass fuels, face high energy costs, and are excluded from centralized electricity grids (Osei-Tutu et al., 2021). Although technological interventions such as mini-grids and solar home systems have expanded in recent years, evidence suggests that infrastructure alone is insufficient to ensure a just and sustainable energy transition (Hamann et al., 2023; Walker and Devine-Wright, 2008). Achieving meaningful change requires approaches integrating technological solutions with inclusive social processes enabling individuals and communities to actively shape energy decisions and practices.

In this context, energy citizenship has emerged to explain how individuals and communities contribute to the advancement of sustainable energy systems (Devine-Wright, 2007; Wahlund and Palm, 2022). Energy citizenship views citizens as active partners in shaping future energy systems rather than as passive consumers. It highlights their role in decision-making, the adoption of renewable technologies, changing behaviors toward energy conservation, and advocating for fair and inclusive energy policies (Curli et al., 2020; Hamann et al., 2023). However, most studies on energy citizenship focus on European contexts, where strong institutional frameworks, participatory governance structures, and decentralized energy infrastructures support citizen engagement (Van der Schoor et al., 2016). In contrast, rural African settings are characterized by institutional weaknesses, infrastructural gaps, and socioeconomic inequalities that complicate efforts to foster similar levels of engagement (Baker et al., 2021; Boamah and Rothfuβ, 2020). Moreover, energy transitions in Africa are deeply embedded in cultural norms of communal decision-making, local governance practices, and the lived experience of energy poverty, dimensions that remain underexplored in the literature (Cloke et al., 2017; Osei-Tutu et al., 2021).

Against this background, there is a need for empirical studies that examine how perceptions, motivations, awareness of policy, and perceived benefits influence community engagement in sustainable energy initiatives across rural African contexts. This is especially relevant in Northern Ghana, where limited energy access and distinct cultural

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and economic conditions present unique challenges for advancing inclusive energy transitions. This study, therefore, investigates the drivers of energy citizenship in Northern Ghana, focusing on how perceptions, motivations, policy awareness, and perceived benefits shape community members' willingness to engage in renewable energy projects. It examines whether perceived benefits strengthen or weaken the relationships between these factors and community engagement, providing insights into the complex dynamics of energy citizenship in rural settings.

This study contributes to literature in two main ways. First, explores the motivations behind community engagement in sustainable energy initiatives, recognizing that such motivations may be shaped by both intrinsic factors, such as environmental responsibility, and extrinsic considerations, such as economic gains and improved social services (Deci and Ryan, 2013; Lennon et al., 2019). Second, it examines how perceptions of renewable energy, awareness of energy policies, and perceived benefits of engagement influence the extent to which rural residents participate in energy-related decision-making. By examining these relationships, the study offers a deeper understanding of the individual and community-based drivers of energy citizenship in contexts where structural barriers and resource constraints often limit active participation.

To address these objectives, the study draws on survey data collected from 678 residents across rural communities in northern Ghana and employs Structural Equation Modeling (SEM) to analyze the relationships among the key constructs. This methodological approach allows for a robust examination of both direct and moderating effects, thereby capturing the complex interactions between perceptions, motivations, policy awareness, perceived benefits, and community engagement. The subsequent part of the paper is organized as follows. The next section presents a comprehensive review of the literature and the conceptual framework guiding the analysis. We then provide a detailed description of the study area, data collection procedures, and analytical methods. The subsequent sections report the empirical results, discuss the findings in relation to existing studies, and conclude with policy recommendations and directions for future research.

2. Background and conceptual framework

Energy citizenship refers to the process by which people and communities transition from being passive energy users to actively engaging with energy systems. The active participation of citizens in adopting sustainable energy practices in their daily lives plays a vital role in driving systemic change and achieving climate neutrality goals (Debourdeau et al., 2024; Silvast and Valkenburg, 2023). This paradigm fosters ownership, democratic participation, and empowerment in energy transitions, thereby reinforcing alignment with global sustainability goals (Walker and Devine-Wright, 2008). This literature review examines community engagement, perceived benefits, and the dynamics of energy citizenship in both developed and developing regions.

2.1. Conceptualizing energy citizenship

Community engagement and perceived benefits play crucial roles in promoting energy citizenship, particularly in rural and underserved areas worldwide, where challenges related to energy access intersect with socioeconomic and environmental dimensions. Foundational work on public attitudes toward renewables (Devine-Wright, 2007) and on the citizen-consumer tension in energy transitions (Lennon et al., 2020) has recently been expanded upon. Dunphy et al. (2025) map the historical roots and possible futures of energy citizenship, while Debourdeau et al. (2024) distinguish instrumental, normative, and transformative modes that operate across household, community, and trans-local scales.

Energy citizenship extends beyond mere access to energy to encompass broader participation in sustainable practices, policy advocacy, and localized energy production (Horstink et al., 2021; Lennon et al., 2020). Studies indicate that fostering energy citizenship is essential for communities to develop resilience and local solutions tailored to specific needs. For example, research on community-driven renewable energy projects in Germany and the UK highlights how active citizen involvement facilitates the deployment of decentralized energy systems, leading to stronger community bonds and increased environmental awareness (Devine-Wright, 2007). Energy citizenship is also gaining traction in regions with limited energy infrastructure, as seen in parts of Sub-Saharan Africa, where local initiatives are critical to achieving energy equity and sustainable development.

2.2. Community engagement in energy systems

Community engagement is a cornerstone of successful energy transitions, fostering trust, accountability, and long-term commitment. The collaborative planning and implementation of energy initiatives ensure alignment with local values and needs, leading to more sustainable outcomes (Walker and Devine-Wright, 2008).

Comparative studies of European energy cooperatives show that democratic governance, transparent benefit-sharing, and deliberative planning build trust and mobilize local capital (Campos and Marín-González, 2020; Schreuer and Weismeier-Sammer, 2010). However, the typology proposed by Debourdeau et al. (2024) warns that pure financial participation may stabilize existing power relations, whereas deliberative or activist forms can open transformative pathways.

Effective engagement has also been observed in Latin America, where local knowledge and participatory approaches have improved project outcomes in solar energy and micro-hydro systems (Drinkwaard et al., 2010).

Empirical evidence from developing regions provides valuable insights into the implementation and benefits of energy citizenship. Studies on microgrids and community-based solar energy in Kenya highlight the role of community engagement and energy initiatives in fostering energy access and economic development, thereby overcoming operational challenges and securing local buy-in. Locals assume roles in maintenance and operation (Ondraczek et al., 2015). Additionally, in India, solar-powered rural electrification projects have empowered communities to manage their energy needs independently, reducing energy poverty and promoting local enterprise (Joshi and Yenneti, 2020; Rai and Maheshwari, 2025). These case studies highlight the need for context-specific approaches that leverage local knowledge and capabilities to enhance both the sustainability and overall impact of energy initiatives.

Research in Ghana demonstrates how local conditions reshape global perspectives on energy transitions. For instance, everyday electricity practices in peri-urban Kumasi reflect aspirations for modernity and social justice (Boamah and Rothfuβ, 2020). Similarly, community leaders in informal settlements emphasize the exclusion of certain groups from formal energy transition processes (Baker et al., 2021). Studies of rural households further reveal the difficult trade-offs individuals face between pursuing environmental goals and maintaining their livelihoods (Boateng et al., 2025). These findings underscore the importance of recognizing local aspirations as a cornerstone for fostering meaningful and sustainable community engagement.

2.3. Perceived benefits and motivations

Perceived benefits and motivators are crucial drivers that impact individuals' willingness to participate and invest in energy initiatives. Benefits include economic opportunities, improved quality of life, and environmental sustainability (Wahlund and Palm, 2022). Across contexts, expectations of local revenue, employment, and lower bills remain powerful motivators (Schreuer and Weismeier-Sammer, 2010). In the Global South, additional drivers include energy security and health benefits from cleaner fuels (Ondraczek et al., 2015), while alleviating

energy poverty can itself be both a cause and a consequence of engagement (Herrejón et al., 2023). Similar outcomes have been observed in Nepal, where community-led micro-hydro projects have provided reliable energy and spurred local development, demonstrating the potential of decentralized systems in underserved regions (Mainali and Silveira, 2011).

Self-Determination Theory (SDT) and Value-Belief-Norm Theory (VBN) provide valuable lens for distinguishing the types of motivations that drive energy engagement and the perceived benefits of energy citizenship. As outlined in Self-Determination theory, intrinsic motivational factors, such as personal responsibility for climate change, community involvement, and the desire to reduce one's carbon footprint, are significant predictors of engagement in energy citizenship (Brizga and Vijaikis, 2024). Also, within the framework of Value-Belief-Norm, ecological values, openness to change, and social norms shape personal norms through awareness of consequences and response efficacy (Farm et al., 2024). Thus, both SDT and VBN theories may provide a robust framework for understanding how the distinct paths, motivations, and perceived benefits interact to influence a stronger community engagement in energy initiatives. Nonetheless, both SDT and VBN were developed in Western contexts; their direct application in the global south requires adaptation, as communal traditions and structural inequalities shape motivations and perceived benefits differently.

Despite its benefits, the promotion of energy citizenship faces several barriers, including financial limitations, policy gaps, and restricted access to technical expertise. In the Global South, high upfront costs of renewable energy technologies and insufficient funding hinder local participation in energy projects (Cloke et al., 2017; Wahlund and Palm, 2022). However, enablers such as supportive policy frameworks, community education, and international partnerships can enhance engagement (Wolsink, 2012). High capital costs, policy incoherence, and limited technical capacity persist (Cloke et al., 2017). Post-Fukushima Japan illustrates how crisis-triggered policy packages, such as feed-in tariffs, community funds, and deregulation, can turn passive publics into prosumers. However, long-term participation depends on sustained public influence over expert committees (Saito, 2021). Similar policy-driven engagement has been observed in Germany, where feed-in tariffs have encouraged community investment in renewable energy cooperatives (Moss et al., 2015).

2.4. Policy awareness and energy transitions

Institutional factors play a pivotal role in shaping the trajectory and effectiveness of energy transitions, particularly through their influence on policy awareness. Policy narratives serve as essential institutional public goods, connecting administrative capacity, corporate innovation, and public engagement (Zheng et al., 2025).

The interactions between institutional structures, societal values, and social learning form the foundation for developing effective energy policies that are responsive to complex socio-technical challenges (Milchram et al., 2019). Institutional factors encompass a wide array of elements, including historical contexts, stakeholder interests, information transparency, and external environmental influences, that shape the pace, direction, and overall success of policy reforms aimed at fostering a sustainable energy future (Agbaam et al., 2025). Similarly, when supported by well-crafted and actively implemented environmental policies, institutional capacity merges as a central driver of energy transition (Carrilho-Nunes and Catalão-Lopes, 2025). Therefore, institutional factors are indispensable for aligning policy design with societal goals for achieving sustainable energy transformations.

2.5. Synthesis and research gap

The new typologies enrich the analytical toolkit, yet longitudinal evidence tracing how motivations, benefits, and identities evolve is scarce. Few studies explicitly model the bidirectional relationship between alleviating energy poverty and expanding citizen agency, especially in rural Ghana. Systematic evaluations of whether engagement redistributes power or accelerates decarbonization also remain limited. Incorporating these recent conceptual and empirical advances provides a more comprehensive basis for analyzing community engagement in sustainable energy transitions. The intertwined challenges of energy poverty, justice, and citizenship necessitate research agendas that focus on transformation, equity, and long-term impact.

3. Methodology

3.1. Hypothesis development

The transition to sustainable energy systems depends on the availability of technological solutions and the extent to which individuals and communities actively participate in shaping energy decisions and practices (Walker and Devine-Wright, 2008). Drawing on insights from SDT and the VBN theory, this study examines how perceptions, motivations, awareness of policy, and perceived benefits influence community engagement in renewable energy initiatives.

Self-Determination Theory suggests that intrinsic motivations, such as environmental concern and social responsibility, are crucial for sustaining long-term behavioral change, while extrinsic motivations, including financial incentives or visible benefits, can further reinforce engagement (Deci and Ryan, 2013; Sierro and Blumer, 2024). The Value-Belief-Norm Theory posits that individuals' values and perceptions of the consequences of environmental issues influence their personal norms, which in turn drive pro-environmental behavior (Lennon et al., 2019). These frameworks provide a foundation for understanding how psychological and contextual factors influence energy citizenship in rural communities.

Building on these theoretical insights, the following hypotheses are proposed.

- H1: Perceptions, motivations, perceived benefits, and awareness of energy policies each have a significant positive effect on community engagement in renewable energy initiatives. This hypothesis reflects the expectation that favorable perceptions, stronger motivations, tangible benefits, and better policy awareness collectively enhance active participation in energy-related decisions.
- H2**:** Perceived benefits moderate the relationships between perceptions, motivations, and community engagement. Specifically, when perceived benefits are high, the positive effects of perceptions and motivations on engagement are expected to be stronger. This hypothesis aligns with the VBN theory, which emphasizes how perceived benefits can enhance personal norms and behavioral intentions toward sustainability (Lennon et al., 2019; Sierro and Blumer, 2024).

3.2. Study area

The study was conducted in Navrongo and its surrounding communities in the Kassena-Nankana Municipal Assembly of Ghana's Upper East Region. The study area spans key sub-districts that serve as a central hub for socioeconomic and administrative activities. Rural and peri-urban settlements, agrarian livelihoods, and a semi-arid climate characterize the area. Fig. 1 situates the study area within the broader national context, highlighting its position in northern Ghana.

Navrongo offers a unique context for studying energy citizenship in rural Sub-Saharan Africa. The area has some of Ghana's lowest electrification rates, with many households relying on traditional biomass fuels, despite hosting Ghana's first utility-scale grid-connected photovoltaic (PV) power plant, which was commissioned in 2013 (Osei-Tutu et al., 2021; Pueyo et al., 2016). The contrast between large-scale energy infrastructure and persistent local energy poverty makes the region an ideal setting for examining how renewable energy investments influence

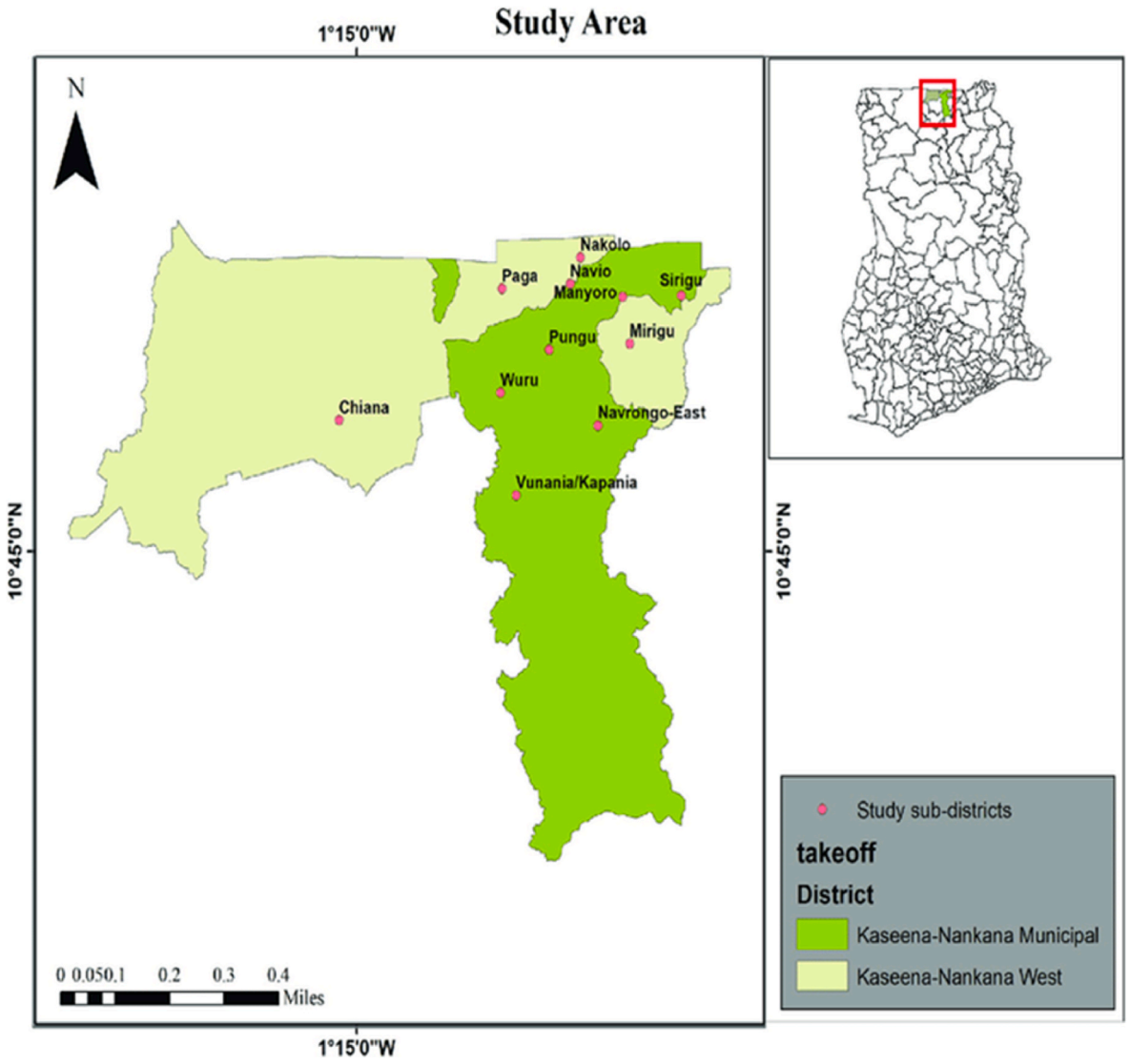


Fig. 1. Map of the study area (Debrah et al., 2020).

community engagement and awareness.

Cultural traditions of collective decision-making and communal land ownership further shape how residents adopt new technologies and participate in energy initiatives (Baker et al., 2021; Boamah and Rothfuβ, 2020). Moreover, while several renewable energy projects, including mini-grids and off-grid solar systems, have been introduced in Northern Ghana, many face sustainability challenges due to limited community involvement, policy awareness, and financing mechanisms (Cloke et al., 2017). Studying Navrongo, therefore, provides insights into how perceptions, motivations, policy awareness, and perceived benefits interact to drive or hinder energy citizenship in contexts marked by both energy innovations and ongoing access challenges.

The survey was administered self-completed between September and October 2023 using a multi-stage random sampling method in rural communities. A total of 678 valid responses were obtained. Respondents were diverse in terms of gender, age, educational level, and occupation. Descriptive statistics and inferential tools, including factor analysis and cross-tabulations, were used for analysis.

3.3. Variable measurements

The variables in this study were measured using a structured questionnaire comprising 24 items, distributed across five constructs: Perceptions, Motivations, Perceived Benefits, Awareness of Policy, and Community Engagement. The initial items were drawn from validated instruments used in prior studies on energy citizenship, community engagement, and pro-environmental behavior (Anthony Jnr, 2020; Lennon et al., 2019; Nikus and Wayessa, 2022).

To ensure contextual relevance, all items were carefully reviewed and adapted for rural Northern Ghana, where linguistic diversity, cultural norms, and communal decision-making practices could influence how concepts are understood. A panel of three energy policy experts and two social scientists evaluated the initial items for cultural appropriateness, technical clarity, and content validity. Terms were simplified or rephrased where necessary to align with local language usage and energy realities. For example, technical references to renewable energy systems were rephrased in terms that are locally familiar, such as "solar power systems."

Pre-testing was conducted with 30 respondents in a community outside the main study area. This pilot phase facilitated the identification of ambiguous terms, the adjustment of response scales to enhance comprehension, and the refinement of items to ensure cultural sensitivity. Feedback confirmed that participants understood the questions as intended and that items captured context-specific dimensions of energy perceptions and motivations.

Reliability analysis using Cronbach's alpha confirmed internal

consistency for all constructs, with alpha values exceeding the recommended threshold of 0.70 (Nunnally, 1978). Convergent and discriminant validity were further examined through Confirmatory Factor Analysis (CFA) prior to hypothesis testing, ensuring that each construct was both statistically and conceptually sound. Table 1 presents the final list of constructs, measurement items, and factor loadings in a clear format, distinguishing between original and adapted items for transparency.

Table 1
Confirmatory Factor Analysis (CFA) summary for constructs.

Construct	Code	Measurement Item	Factor Loading
Perception (α = 0.72; CR = 0.82; AVE = 0.65)	PEC1	Energy applies to all aspects of my daily life.	0.65
	PEC2	Individuals have a role in shaping their energy decisions.	0.72
	PEC3	I feel a sense of responsibility to engage in discussions related to energy.	0.64
	PEC4	I am aware of the energy challenges and opportunities in my community.	0.67
	PEC6	Renewable energy systems can contribute to sustainable development and greater adoption.	0.72
Motivation (α = 0.80; CR = 0.96; AVE = 0.56)	MEC1	I am motivated to reduce my energy consumption and am willing to invest in energy-efficient technologies.	0.62
	MEC2	I am concerned about the environmental impact of traditional energy sources.	0.62
	MEC3	I am confident that my participation in energy activities can reduce carbon emissions.	0.57
	MEC4	I feel empowered to make energy-efficient choices in my daily life.	0.69
Community Engagement (α = 0.72; CR = 0.91; AVE = 0.67)	CEM2	I have opportunities to attend community meetings on energy issues.	0.78
	CEM3	My community actively encourages citizen involvement in energy decisions.	0.71
	CEM4	My community provides educational resources on energy conservation and values citizen input.	0.63
	CEM5	My community promotes active involvement in renewable energy initiatives.	0.85
Perceived Benefits (α = 0.88; CR = 0.97; AVE = 0.64)	PBE1	My engagement in renewable energy can lead to a more sustainable community.	0.63
	PBE2	Participation in energy systems can improve my community's overall quality of life.	0.63
	PBE3	I see potential economic benefits for my community through energy innovation.	0.60
	PBE4	I notice changes in my local area that are connected to climate change.	0.68
	PBE5	Participating in energy initiatives can lower energy costs for residents.	0.57
Awareness (α = 0.83; CR = 0.97; AVE = 0.79)	APR1	Carbon emissions have implications for the environment and human health.	0.65
	APR5	I am aware of government policies and incentives related to renewable energy.	0.70
	APR6	I understand the regulations surrounding energy production and consumption in my area.	0.62
	APR7	I believe government policies support the development of renewable energy.	0.61

3.4. Analysis methods

To examine the direct effects of perceptions, motivations, benefits, and policy awareness on community engagement, a Structural Equation Modeling (SEM) approach was utilized. SEM is a powerful multivariate technique that analyses complex relationships among observed and latent variables, making it well-suited for testing models with multiple constructs and interrelated pathways simultaneously (Collier, 2020; Hair Jr et al., 2021; Kline, 2023). The SEM analysis was performed in two stages: the measurement model and the structural model.

3.4.1. Measurement model

The reliability and validity of the constructs (perceptions, motivations, benefits, and awareness of policy) were first assessed using confirmatory factor analysis (CFA). Key indicators included Cronbach's Alpha for internal consistency (with an acceptable threshold of 0.70 or above) and composite reliability (CR), which should also exceed 0.70 (Fornell and Larker, 1981; Nunnally, 1978). Convergent validity was confirmed if the average variance extracted (AVE) was above 0.50, indicating that the latent construct captured more than half of the variance in the indicators (Fornell and Larker, 1981). Discriminant validity was checked by ensuring that the square root of the AVE for each construct exceeded the correlations with other constructs (Fornell and Larker, 1981).

3.4.2. Structural model

Path analysis was used to examine the relationships between constructs in the SEM framework to test the direct effects. Model fit was assessed with several fit indices: the Chi-square to degrees of freedom ratio (χ^2/df) should be less than 3, indicating an acceptable fit (Byrne, 2001; Malhotra et al., 2014); the Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) should both exceed 0.90; and the Root Mean Square Error of Approximation (RMSEA) should be below 0.08 for an acceptable fit, or below 0.05 for a good fit (Collier, 2020).

3.5. Moderation analysis

The direct influence of an independent variable on a dependent variable can be altered by a third variable, known as a moderator, which impacts the strength of their relationship. This moderator interacts with the independent variable, determining its influence on the dependent variable (Collier, 2020). Various techniques, such as the matched-pairs approach, the full indicator interaction approach, the mixed model approach, and the interaction term approach, can be employed to test moderation (Collier, 2020).

Moderation was tested by creating an interaction term, which is obtained by combining the independent variable and the moderator. This term determined whether the moderator had a significant influence on the relationship between the independent and dependent variables (Collier, 2020). In this study, perceived benefits was adopted as the moderating variable, as illustrated in Fig. 2. Perceived benefits, such as economic, environmental, or social gains, are frequently considered a moderating factor in behavior-related models. In energy-related behavior, these benefits can influence the strength of the relationship between motivational factors and actual engagement. Studies suggest that when individuals perceive higher benefits, their motivation to engage in sustainable energy practices is strengthened (Lennon et al., 2019; Sierro and Blumer, 2024). This view aligns with the Value-Belief-Norm Theory, which posits that perceived benefits can enhance or reduce the effect of personal norms and beliefs on engagement (Sierro and Blumer, 2024).

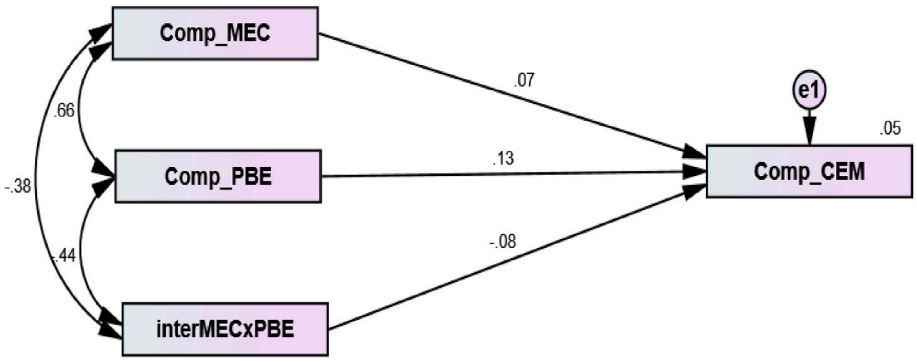


Fig. 2. Moderation model in AMOS.

4. Results

4.1. Measurement model

The measurement model was assessed using Confirmatory Factor Analysis (CFA) to evaluate the reliability and validity of the constructs employed in the study. Table 1 summarizes the constructs, their corresponding items, factor loadings, and internal consistency measures.

All constructs recorded Cronbach's alpha values ranging from 0.72 to 0.88, exceeding the recommended threshold of 0.70 (Nunnally, 1978), indicating satisfactory internal consistency. Similarly, CR values ranged between 0.82 and 0.97, surpassing the minimum criterion of 0.70 (Fornell and Larker, 1981), thus confirming the reliability of the measurement model.

AVE values ranged from 0.56 to 0.79, above the recommended minimum of 0.50 (Fornell and Larker, 1981), indicating that the underlying latent constructs explained more than 50 % of the variance in the indicators. Moreover, all factor loadings exceeded the acceptable threshold of 0.50, with most above 0.60, demonstrating strong item-to-construct relationships (Hair Jr et al., 2021).

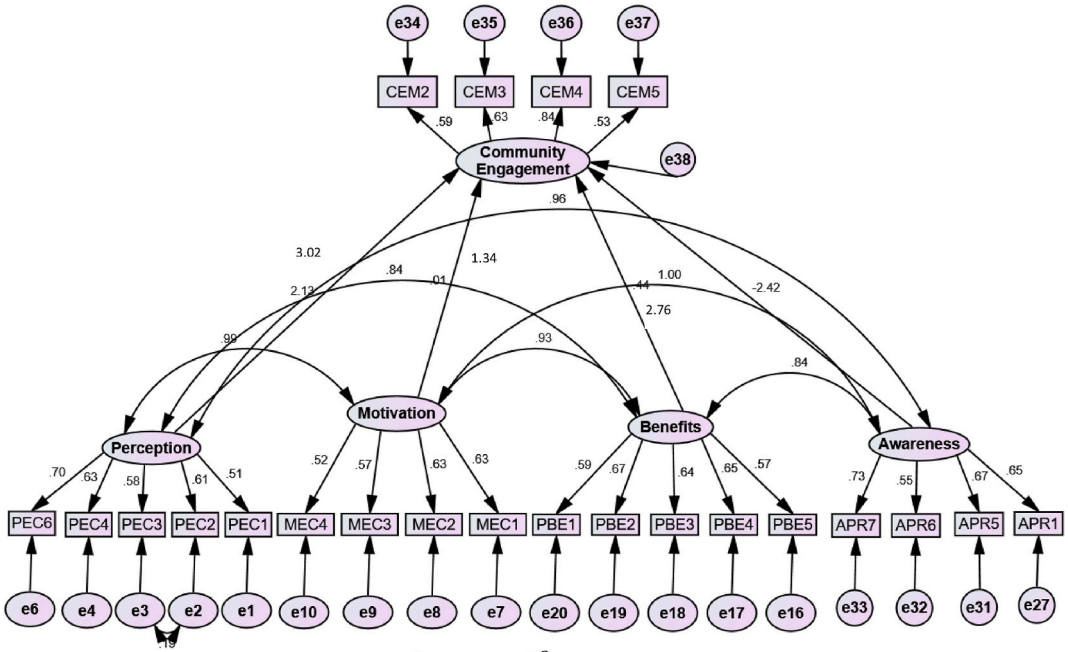
Discriminant validity was established by confirming that the square root of the AVE for each construct exceeded its correlations with other constructs (Fornell and Larker, 1981). This test indicates that each construct is conceptually distinct and captures phenomena not represented by other latent variables in the model.

The measurement model demonstrates satisfactory reliability, convergent validity, and discriminant validity, providing a sound basis for testing the structural relationships among perceptions, motivations, perceived benefits, policy awareness, and community engagement in the subsequent analysis.

4.2. Structural model

After confirming the adequacy of the measurement model, the hypothesized structural relationships among perceptions, motivations, perceived benefits, policy awareness, and community engagement were tested using AMOS as illustrated in Fig. 3.

The hypothesized model demonstrated a satisfactory fit to the data, as indicated by multiple goodness-of-fit indices. The Chi-square to degrees of freedom ratio (χ^2/df) was 2.88, below the recommended cutoff value of 3.0, indicating an acceptable fit (Byrne, 2001; Malhotra et al., 2014). The Comparative Fit Index (CFI) and Incremental Fit Index (IFI) both exceeded the 0.90 threshold (Collier, 2020), while the Root Mean Square Error of Approximation (RMSEA) was below the 0.08 cutoff,



$Model\ Fit\ Statistics: X^2 = 603.384.\ {}^{d}/_{f} = 210.\ {}^{X^2}/_{df} = 2.873\ CFI = .902. TLI = .882. RMSEA = 0.053$

Fig. 3. Structural model.

further confirming the model's adequacy. Taken together, these indices suggest that the structural model provides a robust representation of the relationships among the study variables.

Standardized estimates and critical ratio (C.R) t values are utilized to evaluate the direct effects. Table 2 summarizes the structural model test results, examining the direct effects of key factors, perceptions, motivations, benefits, and awareness of policy on community engagement. Each hypothesized relationship was tested to determine the significance of its effect on engagement levels within the community.

The findings in Table 2 provide empirical support for the influence of perceptions, motivations, and perceived benefits on community engagement, while awareness of policy shows no statistically significant effect. This nuanced understanding aligns with and diverges from existing literature on community engagement and policy impact, as discussed below.

Perception and Community Engagement (H1a): The strong positive relationship between perception and engagement ($\beta = 3.021$, $p < 0.01$) underscores the importance of favorable perceptions in enhancing community involvement. This finding aligns with previous studies, such as those by Boudet (2019), which identified perception as a critical driver of active participation in environmental initiatives. Moreover, Esiri et al. (2023) and Rogers et al. (2008) found that positive perceptions of project benefits were highly correlated with greater engagement in local energy projects. These results emphasize that initiatives to improve perceptions could be pivotal in maximizing community participation and support.

Motivation and Community Engagement (H1b): Motivation significantly influences engagement ($\beta = 1.342$, $P = 0.034$), consistent with the findings of Sierro and Blumer (2024), who identified intrinsic motivation as an essential factor for sustained community involvement in sustainability projects. This result suggests that motivation plays a fundamental role in catalyzing engagement, supporting the premise that communities with intrinsic motivation and a clear understanding of the long-term benefits are more likely to engage actively in policy-related initiatives.

Perceived Benefits and Community Engagement (H1c): The direct positive impact of perceived benefits on engagement ($\beta = 2.756$, $p < 0.05$) aligns with findings from Lennon et al. (2019) who demonstrated close linkages of perceived community benefits with community participation and ownership of renewable energy projects. The alignment of these findings underscores that when communities perceive clear benefits, they are more inclined to participate in initiatives, highlighting the need for policies that effectively communicate such benefits.

Awareness of Policy and Community Engagement (H1d): Unlike perceptions, motivation, and benefits, awareness ($\beta = -2.420$, $p = 0.069$) showed no statistically significant effect on community engagement at the conventional 0.05 level. While this suggests that awareness alone may be insufficient to stimulate active participation, the near significance ($p < 0.10$) indicates that its impact may emerge more clearly under conditions where supportive structures or perceived benefits are stronger (Blečić et al., 2023).

The structural model explains 68.4 % of the variance ($R^2 = 0.684$) in community engagement, indicating strong predictive power. In behavioral and social science research, R^2 values above 0.50 are generally considered strong (Hair Jr et al., 2021). Comparable studies on community participation in energy transitions often report R^2 values between 0.40 and 0.60 (Zaharuddin et al., 2025), making the current value relatively high. These findings suggest that perceptions, motivations, and perceived benefits are robust predictors of energy citizenship in rural Ghana.

Table 2
Structural model test results.

Hypothesized Relationships	Estimates (β)	T Value	P-Value	Hypothesis
H1a: Perception → Engagements	3.021	2.861	0.004	Supported
H1b: Motivation → Engagements	1.342	2.129	0.034	Supported
H1c: Benefits → Engagements	2.756	2.501	0.012	Supported
H1d: Awareness → Engagements	−2.420	−1.821	0.069	Not Supported
Squared Multiple Correlation (R^2)	0.684			

4.3. Moderation analysis

4.3.1. Moderating effect of perceived benefits on the relationship between perception and community engagement

Table 3 presents the moderation test for the interaction between perception and perceived benefits. The direct effects of perception and perceived benefits on community engagement were both positive and significant. Notably, the interaction term was also significant and positive ($\beta = 0.14$, $p < 0.05$), confirming that perceived benefits strengthen the relationship between perceptions and community engagement.

These findings suggest that individuals with high perceived benefit are more likely to act on their positive perceptions (such as awareness or attitude toward renewable energy) and engage in community projects. Conversely, even if people have strong perceptions about the importance of energy projects, if they do not see tangible benefits, their likelihood of engaging remains low. The perceived benefits of energy citizenship represent individuals' efforts to understand the impacts of climate change and adopt renewable energy technologies. Additionally, these perceived benefits can influence the relationship between the adoption of renewable energy technology and community engagement, impacting the overall quality of life (Anthony Jnr, 2020).

4.3.2. The effect of perceived benefits on the relationship between motivation and community engagement

The moderation test for motivation is reported in Table 4. Motivation and perceived benefits each had significant positive effects on community engagement. However, the interaction term was negative and statistically significant ($\beta = -0.10$, $p < 0.01$).

These findings suggest that the relationship between perceived benefits and engagement diminishes as motivation increases, which contrasts with Self-Determination Theory (Deci and Ryan, 2013), where intrinsic motivation, combined with perceived benefits, is generally expected to amplify engagement. One possible reason is that individuals with high motivation may discount perceived benefits, viewing them as secondary or even as distractions from their intrinsic goals. This finding partially aligns with Omoto and Snyder (2002), who discussed motivational crowding-out, where external incentives might undermine intrinsic motivations, leading to reduced participation.

5. Discussion

The moderation analysis provides deeper insight into the dynamics of energy citizenship in rural Northern Ghana. The finding that

Table 3
Moderation of perceived benefits × perceptions → engagement.

Hypothesized Relationship	Estimates	t value	P-Value	Results
Perception → Community Engagement	0.310	3.05	0.002	
Perceived Benefits → Community Engagement	0.285	2.92	0.004	
INT_Perceived benefits X perception → Community Engagement	0.142	2.47	0.0014	Supported

Table 4
Moderation of perceived benefits × motivation → engagement.

Hypothesized Relationship	Estimates	t value	P-Value	Results
Motivation → Community Engagement	0.228	4.65	***	
Perceived Benefits → Community Engagement	0.192	3.88	***	
INT_Perceived benefit X Motivation → Community Engagement	−0.096	−2.89	0.004	Supported

perceived benefits strengthen the perception–engagement relationship underscores the importance of visible community-level outcomes in translating favorable perceptions into active participation. When residents observe tangible benefits such as reduced energy costs, improved service reliability, or opportunities for local development, their positive attitudes toward renewable energy are more readily converted into sustained engagement. This result is consistent with prior research demonstrating the pivotal role of perceived benefits in enhancing community participation and ownership of energy initiatives (Joshi and Yenneti, 2020; Kirubi et al., 2009; Lennon et al., 2019). It also aligns with the VBN framework, which emphasizes how perceived gains amplify personal norms and behavioral intentions (Lennon et al., 2019).

Conversely, the moderating effect of perceived benefits on the motivation-engagement relationship reveals evidence of a motivational crowding-out effect. While motivation itself remains a strong predictor of engagement, the introduction of extrinsic benefits appears to weaken this link. This outcome resonates with Self-Determination Theory (Deci and Ryan, 2013), which cautions that external incentives may undermine intrinsic motivations. Similar findings have been reported in studies of voluntary environmental and community behavior, where an overemphasis on rewards has been shown to diminish the intensity of intrinsically driven engagement (Frey and Jegen, 2000; Omoto and Snyder, 2002). In the Ghanaian context, this suggests that although residents are motivated by social responsibility and environmental concern, engagement strategies that place disproportionate emphasis on financial or material incentives risk eroding these intrinsic drivers.

These findings highlight the need for a balanced policy approach. On one hand, policymakers and practitioners should prioritize communicating and delivering tangible community benefits, as these strengthen the impact of positive perceptions. On the other hand, engagement strategies should avoid an overreliance on extrinsic incentives. Instead, they should foster voluntary participation, community ownership, and recognition mechanisms that preserve and reinforce intrinsic motivations (Campos and Marín-González, 2020; Wahlund and Palm, 2022). Such an approach is particularly critical in rural African contexts, where structural barriers and limited trust in centralized policy frameworks often constrain participation (Baker et al., 2021; Boamah and Rothfuβ, 2020).

More broadly, the findings extend the conceptualization of energy citizenship by demonstrating how intrinsic and extrinsic motivational dynamics interact to shape engagement. They also illustrate that while perceptions and motivations remain vital, the perceived benefits of renewable energy initiatives play a decisive role in determining whether favorable attitudes and intentions translate into meaningful action. In doing so, the study contributes to ongoing debates on energy justice and inclusive energy governance (Cloke et al., 2017; Hamann et al., 2023).

5.1. Limitations and future research

This study provides new insights into energy citizenship in Northern Ghana; however, certain limitations remain. A cross-sectional design restricts causal inference, making it challenging to determine the direction of relationships among perceptions, motivations, perceived benefits, and community engagement. Longitudinal studies would help track how these dynamics evolve as energy projects mature and communities gain experience (Debourdeau et al., 2024; Dunphy et al., 2025).

Theoretical frameworks such as Self-Determination Theory and the Value-Belief-Norm model originate from Western contexts. Their application in Sub-Saharan Africa is shaped by cultural norms, communal traditions, and structural inequalities that influence how motivations and perceived benefits operate (Baker et al., 2021; Boamah and Rothfuβ, 2020). Future work should adapt and extend these models to better reflect the diverse socio-cultural realities of Africa.

The moderation analysis revealed contrasting effects of perceived benefits; however, the mechanisms underlying these dynamics remain unclear. The crowding-out effect observed in the motivation–engagement pathway points to complex interactions between intrinsic and extrinsic drivers. Mixed method approaches that combine surveys with interviews or focus groups could clarify these processes (Cloke et al., 2017; Hamann et al., 2023).

The study also focuses on Northern Ghana, which limits its generalizability. Although this region is a relevant case due to its energy access challenges, the findings may not apply to other African contexts or urban areas. Comparative studies across diverse socioeconomic and infrastructural settings are needed to test the robustness of these drivers of energy citizenship (Osei-Tutu et al., 2021).

By addressing these gaps, future research can build a more comprehensive understanding of how perceptions, motivations, and benefits interact to shape energy citizenship and inform policies that balance intrinsic motivations with tangible community outcomes.

6. Conclusion

This study examined the factors influencing energy citizenship in rural Northern Ghana, focusing on perceptions, motivations, perceived benefits, and policy awareness as predictors of community engagement in sustainable energy transitions. The findings reveal that perceptions, motivations, and perceived benefits significantly enhance community participation in renewable energy initiatives, while policy awareness alone does not yield a statistically significant effect. Additionally, perceived benefits were found to strengthen the positive impact of perceptions on engagement but unexpectedly weakened the influence of motivation, suggesting the presence of motivational crowding-out effects in some contexts.

These results highlight that advancing energy citizenship in rural Africa requires more than simply providing technical infrastructure or policy directives. Active community participation emerges when individuals recognize tangible benefits, feel intrinsically motivated, and perceive renewable energy initiatives as relevant to their social and economic well-being. At the same time, the limited effect of policy awareness underscores the need for governance approaches that link national energy strategies with local realities through participatory and inclusive mechanisms.

Overall, the study enriches the literature by integrating Self-Determination Theory and the Value-Belief-Norm framework into the African energy transition context, demonstrating that both individual psychological drivers and institutional factors shape community engagement in renewable energy projects. By contextualizing energy citizenship within the socioeconomic landscape of Northern Ghana, this research emphasizes the potential of tailored, benefit-oriented engagement strategies that resonate with community members' everyday experiences. In doing so, it contributes to a growing body of literature on the importance of localized and inclusive approaches to sustainable energy transitions, supporting global evidence that perceptions, personal motivations, and perceived benefits are crucial to cultivating a robust energy citizenship framework.

6.1. Policy implications

Based on these findings, several policy and practical

recommendations emerge for governments, development agencies, and energy practitioners seeking to promote energy citizenship and accelerate sustainable energy transitions in rural Sub-Saharan Africa.

- Policies should institutionalize participatory mechanisms such as community energy forums, co-ownership models, and citizen advisory committees. These structures can bridge the gap between national policy goals and local energy realities, ensuring that rural communities are active partners in designing, implementing, and monitoring energy projects.
- Tangible improvements in energy access, affordability, and reliability should accompany awareness campaigns. Demonstrating concrete benefits, such as reduced energy costs, improved education and healthcare services, and local economic opportunities, can translate knowledge into sustained community engagement.
- Integrating energy literacy programs into rural schools, vocational training centers, and community organizations can foster long-term awareness and participation. Training local technicians and energy entrepreneurs can also build the technical capacity needed to sustain renewable energy systems beyond initial project cycles.
- While subsidies, tax incentives, or revenue-sharing schemes can encourage adoption, over-reliance on financial rewards risks diminishing voluntary, value-driven engagement. Incentive structures should strike a balance between extrinsic benefits and opportunities for voluntary leadership, recognition, and communal decision-making to preserve intrinsic motivations for participation.
- Decentralizing energy governance through local energy committees or district-level energy offices can improve responsiveness to community needs and enhance trust in energy policies. Such structures enable tailored solutions that reflect the unique cultural, economic, and social contexts of rural communities.

CRediT authorship contribution statement

Albert Kotawoke Awopone: Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Project administration, Methodology, Formal analysis. **Abdul-Latif Ayariga Amidu:** Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Sarpong Hammond Antwi:** Writing – review & editing, Validation, Supervision, Project administration, Investigation. **Patrick Nyaaba Ayambire:** Writing – review & editing, Validation, Supervision. **Isaac Prempeh:** Writing – review & editing, Supervision, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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