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Energy Anxiety and Subjective Wellbeing Among Marginalised Communities: Evidence From Rural India

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Abstract

This study investigates the construct of Energy Anxiety among marginalised communities in Baripada district, Odisha. The purpose is to understand how persistent worry related to affordability, reliability, and safety of energy access affects the subjective wellbeing of low-income and Scheduled Tribe households. The study responds to the limited scholarship on the psychological dimensions of energy poverty in eastern India. A cross-sectional household survey was conducted among 240 respondents across ten villages in Baripada. The newly developed Energy Anxiety Index (EAI) was validated using reliability and factor analyses. Measures of subjective wellbeing (life satisfaction, positive affect, negative affect) were incorporated. Data were analysed using descriptive statistics, correlations, and Partial Least Squares Structural Equation Modelling to assess direct and moderating effects. Results indicate high levels of energy anxiety (Mean = 4.08/5), driven by unpredictable outages, increasing energy expenditure, and fear related to unsafe cooking practices. Energy anxiety is associated with lower life satisfaction ($\beta = -0.307$, $p < 0.001$) and positive affect ($\beta = -0.290$, $p < 0.001$), and higher negative affect ($\beta = 0.330$, $p < 0.001$). Moderation analysis showed that households with irregular electrification and those dependent on biomass fuels reported the strongest adverse effects. The study is geographically limited to one district and uses a cross-sectional design. However, the findings offer clear implications for energy justice interventions and targeted welfare policies. The study introduces a novel measure of Energy Anxiety and demonstrates its relevance for understanding subjective wellbeing in marginalised rural contexts, contributing a new psychological dimension to energy poverty research.

Keywords: Energy anxiety, Energy poverty, Marginalised communities, Rural Odisha, Subjective wellbeing

1. Introduction

Energy plays a foundational role in economic development and social wellbeing (Acheampong et al., 2021). It underpins productive activities, enables access to essential services, and supports improvements in living standards. Beyond its economic function, energy is integral to addressing broader development challenges, including poverty reduction, health outcomes, educational attainment, and overall quality of life (Carvalho & Santos, 2024). At the global level, significant progress has been made in expanding access to electricity. Between 2010 and 2021, global electricity access increased from 84% to 91%, with particularly strong gains in South Asia, including India. Large-scale electrification programmes have substantially reduced the number of people without formal electricity connections (World Bank, 2023). However, growing evidence suggests that improvements in access have not been matched by comparable improvements in the quality, reliability, and stability of energy services, particularly in rural and least-developed regions (Akter et al., 2023).

In many developing countries, households formally connected to electricity networks continue to experience frequent power interruptions, voltage fluctuations, rising energy costs, and limited-service dependability (Meles et al., 2021). Similar challenges persist in access to clean and safe cooking energy, where households often rely on inefficient or hazardous fuels. These conditions indicate that energy deprivation cannot be understood solely in terms of access or consumption. Instead, households may remain connected to energy systems while facing persistent insecurity in everyday energy use (Eisfeld & Seebauer, 2022).

Energy poverty is commonly conceptualised as the inability of households to secure adequate, reliable, and affordable energy services necessary for a decent standard of living. It reflects deprivation in access to essential energy services required to maintain health, comfort, and social participation (Manasi & Mukhopadhyay, 2024). While income poverty and energy poverty are often assumed to move together, empirical evidence suggests that this relationship is context-specific. In rural India, income poverty does not always translate into energy security, indicating that energy deprivation operates through mechanisms distinct from income alone (Gupta et al., 2020). Recent evidence from South Asian contexts further highlights that household energy insecurity is shaped by intersecting factors, including caste, housing quality, and spatial location, which moderate the relationship between income and energy access (Manasi & Mukhopadhyay, 2024; Patnaik & Jha, 2020)

The consequences of energy poverty extend beyond material deprivation and have important implications for public health and wellbeing. Inadequate access to energy is associated with unsafe indoor temperatures, exposure to indoor air pollution, and reduced capacity to maintain healthy living environments. These risks disproportionately affect disadvantaged households and are increasingly recognised as major public health concerns (Bentley et al., 2023). Empirical studies have linked energy-related deprivation to a range of physical and mental health outcomes, including respiratory illness, cardiovascular conditions, stress, depression, and anxiety (Bentley et al., 2023; Hashmi et al., 2025).

Despite this growing recognition, much of the existing literature focuses on objective indicators such as energy expenditure, service disconnection, or access deficits, while paying limited attention to how households experience energy insecurity psychologically (Gupta et al., 2020). For many households, energy-related difficulties generate persistent worry about paying bills, coping with service disruptions, managing safety risks, and ensuring future access. These concerns are not isolated events but recurring stressors that shape daily routines, decision-making, and emotional wellbeing. Yet, the psychological dimensions of energy insecurity remain insufficiently examined in empirical energy research, particularly in rural and low-income contexts.

To address this gap, this study introduces the concept of energy anxiety to capture the psychological experiences associated with insecure energy access. Energy anxiety is conceptualised as persistent worry and stress related to four interconnected dimensions of household energy access: affordability, reliability, safety, and future security. Unlike general anxiety, energy anxiety is domain-specific and rooted in concrete, recurring energy-related concerns. It reflects how households perceive and emotionally respond to unstable energy conditions rather than the conditions themselves.

At the same time, psychological responses to energy insecurity are shaped by broader structural environments. The concept of energy precarity has been used to describe conditions of persistent instability in energy provision, arising from unreliable services, inadequate infrastructure, unsafe energy arrangements, and limited capacity to secure dependable energy over time (Petrova, 2018). Energy precarity highlights how vulnerability is produced through institutional, infrastructural, and socio-spatial arrangements rather than individual circumstances alone (Petrova, 2018; Simcock et al., 2016). Importantly, energy precarity refers to a structural condition rather than an emotional state, distinguishing it analytically from psychological responses such as anxiety.

Understanding the interaction between energy anxiety and energy precarity is essential for assessing the wellbeing impacts of energy poverty (Mayer & Smith, 2019). Psychological stress related to energy insecurity may exert stronger effects on wellbeing in highly precarious energy environments, where disruptions are frequent and coping options are limited (Hernández, 2016). Conversely, more stable and predictable energy services may reduce the intensity of energy-related worry and mitigate its effects on wellbeing.

These issues are particularly relevant for subjective wellbeing, which encompasses both cognitive evaluations of life satisfaction and affective experiences such as positive and negative emotions (Nima et al., 2024). Extensive research in wellbeing studies demonstrates that chronic stressors associated with financial strain, uncertainty, and perceived risk adversely affect emotional wellbeing and overall life satisfaction (Ryu & Fan, 2023). Given its persistent and anticipatory nature, energy-related worry is likely to influence both daily emotional experiences and broader life evaluations. However, empirical evidence linking energy-related psychological stress to subjective wellbeing outcomes remains limited, especially in rural and marginalised settings.

Against this background, the present study examines the relationship between energy anxiety and subjective wellbeing among rural households in Baripada district, Odisha, and investigates the moderating role of energy precarity in this relationship. By integrating psychological and structural dimensions of energy insecurity, the study contributes to a more comprehensive understanding of how energy poverty affects wellbeing beyond material deprivation.

2. Literature Review

2.1 Energy Anxiety

Energy-related stress is increasingly recognised as an important but underexamined dimension of deprivation among low-income and marginalised populations. Research on housing and neighbourhood disadvantage shows that poor housing quality, residential instability, lack of affordability, and deprived living environments constitute persistent sources of stress that disproportionately affect vulnerable households (Hernández et al., 2016; Santiago et al., 2011). Within this broader context, difficulties in meeting household energy needs — conceptualised as energy insecurity, or the inability to adequately secure essential energy services — have emerged as a significant contributor to chronic psychological strain (Hernández, 2013). Conservation of Resources (COR) Theory offers a useful explanatory lens here: it proposes that stress arises not only from the actual loss of valued resources but from the persistent threat of such loss (Hobfoll, 1989). Energy access, as a foundational input to health, safety, and daily functioning, constitutes precisely such a resource, and its chronic instability places households in a sustained state of psychological threat rather than discrete deprivation.

Existing instruments for measuring energy insecurity — including the Household Energy Insecurity Experience scale (Hernández et al., 2016) and objective indicators commonly used in South Asian research such as fuel type, connection status, or expenditure share (Gupta et al., 2020; Manasi & Mukhopadhyay, 2024) — largely capture what households materially experience or behaviourally do under conditions of energy deprivation. As (Hashmi et al., 2025) have recently argued, such measures are likely to underestimate the psychological burden of energy insecurity, since they do not assess how households emotionally respond to or anticipate energy-related difficulties. The Energy Anxiety Index (EAI) developed in this study addresses this gap by capturing the domain-specific psychological appraisal of energy insecurity across four dimensions — affordability, reliability, safety, and future security — distinguishing it conceptually from both objective deprivation measures and general psychological distress scales.

Affordability constraints represent a primary pathway through which energy insecurity generates psychological stress. Low-income households frequently worry about paying energy and household bills amid economic insecurity, inefficient housing, and rising fuel costs (Hernández, 2016; Manongi et al., 2024). Evidence links unaffordable housing and utility costs to adverse health outcomes, including poor self-rated health, hypertension, and depression (Ettman et al., 2020). In the energy context, constant monitoring of consumption, anticipation of bills, and fear of arrears or service disconnection contribute to sustained economic stress and undermine a stable sense of home and security (Hernández et al., 2016).

Unreliable energy supply constitutes a second major source of energy-related anxiety. Frequent power outages and service interruptions disrupt daily routines and compromise access to heating, cooling, food storage, water, and healthcare. Global evidence shows that power outages are associated with a wide range of adverse health outcomes, including temperature-related illness, carbon monoxide poisoning, infections, and mortality (Casey et al., 2020). Supply unreliability is particularly significant from a COR perspective because it generates a condition of continuous resource threat — households cannot plan around energy availability, meaning the psychological burden is ongoing rather than episodic.

Safety concerns related to household energy use form a distinct dimension of energy anxiety. In contexts of poor housing quality and energy insecurity, households often rely on coping strategies such as under-heating or using unsafe devices, including space heaters or stoves, to meet basic energy needs. These practices increase risks of accidents, fires, indoor air pollution, and carbon monoxide exposure (Hernández, 2016). Research links unsafe energy practices and substandard energy systems to respiratory disease, cardiovascular outcomes, injuries, and heightened mental health risks (Bhui et al., 2023; Jessel et al., 2019). Persistent concern about health and safety, particularly for children and older household members, contributes to ongoing psychological stress, and is especially salient in rural Indian contexts where dependence on biomass fuels remains high among Scheduled Tribe households.

Beyond immediate concerns, households often experience anxiety related to the future security of energy access. Fear of unaffordable future bills, service disconnection, or worsening energy conditions motivates coping behaviours such as energy rationing and reduced usage (Hernández, 2016). Financial burdens and residential instability generate anticipatory worry and diminished wellbeing, reflecting uncertainty about the sustainability of energy access over time (Manongi et al., 2024). Chronic exposure to such stressors may create a self-reinforcing cycle — consistent with COR Theory's resource loss spiral, wherein depletion of coping resources increases vulnerability to further harm (Hobfoll, 1989) — intensifying psychological strain over time. Research evidence from India confirms that inadequate or inconsistent supply, combined with limited accessibility or affordability, can significantly undermine the overall wellbeing of communities (Acharya & Sadath, 2019; Haider et al., 2024; Singh Bahi & Paavola, 2024).

2.2 Energy precarity as a structural and spatial condition

Energy precarity has been developed in the literature to capture forms of persistent instability and vulnerability in household energy access that extend beyond temporary shortages or isolated affordability problems. Petrova (2018) conceptualises energy precarity as the inability to secure socially and materially necessary levels of domestic energy, produced through the interaction of governance practices, housing conditions, and spatial inequalities. This perspective shifts attention away from individual household characteristics toward the political, infrastructural, and spatial arrangements that structure everyday energy access. Importantly, energy precarity operates as a structural condition — an objective feature of the energy environment — rather than a psychological state, and it is analytically distinct from the anxiety responses it may generate. This distinction maps onto the Stress Process Model (Pearlin et al., 1981), which separates primary structural stressors from the secondary psychological responses they produce; in this framework, energy precarity constitutes the structural stressor, while energy anxiety represents the psychological response, and subjective wellbeing is the downstream outcome.

A key contribution of the energy precarity framework is its emphasis on materially and politically induced instability in energy provision. (Petrova, 2018) explicitly distinguishes energy precarity from subjective experiences such as worry or anxiety, while noting that precarious energy conditions create the context in which such psychological responses emerge. Energy precarity thus refers to objective exposure to unstable and inadequate energy systems, including unreliable supply, inefficient infrastructure, and constrained energy choices, rather than to emotional states themselves.

This structural understanding is reinforced by spatial approaches to energy justice. (Bouzarovski & Petrova, 2015) highlights that energy poverty and vulnerability are deeply spatial phenomena, shaped by infrastructure networks, planning decisions, and uneven patterns of development. From this perspective, households may remain exposed to poor quality energy supply, unsafe systems, and limited alternatives even when they are nominally "connected" to the grid. Spatial inequalities in infrastructure investment and service provision therefore play a central role in producing energy precarity.

Theoretical work grounded in the capabilities approach further supports this distinction between conditions and outcomes. (Day et al., 2016) conceptualises energy deprivation as a constraint on household capabilities—such as the ability to maintain comfort, protect health, and participate socially—rather than as a direct measure of subjective wellbeing. This framework allows energy precarity to be treated as an objective limitation on resources and opportunities, which may subsequently shape emotional and wellbeing outcomes without being reducible to them.

Empirical research also suggests that energy precarity has both direct and indirect implications for wellbeing. (Phillips & Petrova, 2021) demonstrates that precarious energy infrastructures can directly restrict capabilities related to health, comfort, and social participation, while simultaneously intensifying stress, anxiety, and other emotional harms. Together, these perspectives position energy precarity as a structural condition that not only constrains everyday functioning but also amplifies the psychological impacts of energy-related insecurity. From a COR perspective, this amplification reflects a resource loss spiral dynamic: households already exposed to structurally precarious energy conditions have fewer resources available to buffer the psychological burden of energy anxiety, making the wellbeing consequences of worry disproportionately severe under precarious conditions — a proposition directly examined through the moderation analysis in this study.

2.3 Hypothesis Development

Drawing on the conceptual distinction between psychological and structural dimensions of energy insecurity, we propose three sets of hypotheses (Figure 1). First, energy anxiety is expected to adversely affect subjective wellbeing by reducing life satisfaction and positive affect while increasing negative affect. Second, energy precarity is hypothesised to have an independent negative association with subjective wellbeing, reflecting the direct constraints imposed by unstable and inadequate energy systems. Third, energy precarity is expected to moderate the relationship between energy anxiety and wellbeing, such that the adverse effects of energy anxiety are amplified under more precarious energy conditions.

H1: Energy anxiety is negatively associated with (a) life satisfaction and (b) positive affect, and positively associated with (c) negative affect.

H2: Energy precarity is negatively associated with (a) life satisfaction and (b) positive affect, and positively associated with (c) negative affect.

H3: Energy precarity moderates the relationship between energy anxiety and subjective wellbeing, strengthening its negative effects on (a) life satisfaction and (b) positive affect, and its positive effect on (c) negative affect.

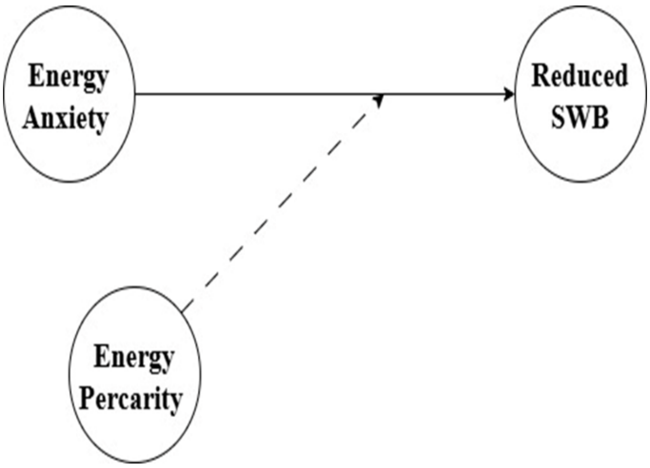

Figure 1. Conceptual research model
Source: created by the author

3. Methods

3.1 Research Design and Sampling

The study employed a cross-sectional field survey design conducted across ten rural villages in the Baripada district of Odisha, India. Household-level primary data were collected using a multi-stage purposive cluster sampling approach, with villages treated as clusters and households selected within each cluster. The selection of villages was informed by the Census of India (2011) data, with particular emphasis on areas characterised by higher concentrations of marginalised communities, frequent energy supply disruptions, and limited access to reliable energy infrastructure.

A structured household survey was administered across the selected villages. In total, 272 surveys were conducted, of which 240 responses were retained for analysis after data cleaning and the exclusion of incomplete or inconsistent responses, as shown in Table 1. One adult respondent was selected from each household. Participation in the survey was voluntary, and informed consent was obtained from all respondents prior to data collection. Respondents were informed of the study's purpose and were free to withdraw at any time.

All data collection procedures were conducted in accordance with the host institution's ethical guidelines. Participation was voluntary, written informed consent was obtained from all respondents prior to data collection, and confidentiality of responses was maintained throughout. No personally identifiable information was retained in the dataset used for analysis.

Table 1. Demographic details

	Category	Frequency (n)	Percentage (%)
Gender	Male	138	57.5
	Female	102	42.5
Age group (years)	18–30	54	22.5
	31–45	96	40
	46–60	63	26.3
	Above 60	27	11.2
Education level	No formal education	68	28.3
	Primary education	79	32.9
	Secondary education	66	27.5
	Higher secondary & above	27	11.3
Household monthly income	Below ₹5,000	92	38.3
	₹5,001–₹10,000	88	36.7
	₹10,001–₹15,000	43	17.9
	Above ₹15,000	17	7.1
Social category	Scheduled Tribe	179	74.4
	Scheduled Caste	61	25.6

Source: Primary Data

To assess sample adequacy, a brief a priori power analysis was conducted using G*Power (Faul et al., 2009). Following standard practice in PLS-SEM, the analysis was based on the most complex endogenous construct in the model, which included three predictors. Using a medium effect size ($f^2 = 0.15$), a significance level of 0.05, and statistical power of 0.80, the minimum required sample size was 77. Given that the present study includes 240 respondents, the sample size is considered adequate to detect meaningful effects.

3.2 Measurement and Instrument Development

The measurement instrument was designed to capture both the structural conditions of energy access and the psychological dimensions of energy-related stress. The questionnaire comprised four main components: Energy Anxiety Index (EAI), Energy Precarity (EP), Life Satisfaction (LS), and Affective Wellbeing (SPANE).

The Energy Anxiety Index (EAI) was developed for this study to capture the psychological and anticipatory dimensions of energy-related stress, including affordability concerns, reliability uncertainty, safety risks, and future-oriented energy insecurity. The items were informed by existing literature on energy insecurity and psychological stress/appraisal frameworks, and were adapted to reflect the lived experiences of rural households. The Energy Precarity (EP) construct captures the structural conditions of household energy access, including supply interruptions, voltage instability, and constraints in energy service use.

Subjective wellbeing was assessed using established and validated instruments. Life satisfaction was measured using the Satisfaction with Life Scale (SWLS) (Diener et al., 1985), consisting of five items rated on a 7-point Likert scale. Affective wellbeing was measured using the Scale of Positive and Negative Experience (SPANE) (Jovanović, 2015), comprising ten items capturing positive and negative emotional experiences over the past four weeks, measured on a 5-point frequency scale.

To ensure linguistic and contextual appropriateness, the questionnaire was translated into the local language and subsequently back-translated into English by independent bilingual translators to ensure semantic equivalence. Minor discrepancies were resolved through discussion among the research team. The instrument was pretested with a small sample of respondents to assess clarity, comprehension, and contextual relevance, and minor revisions were made accordingly. All items for EAI and EP were measured using a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). Full item wording for all constructs is provided in the Appendix (Table 5).

3.3 Data Analysis

Partial Least Squares Structural Equation Modelling (PLS-SEM) was employed due to its suitability for prediction-oriented and exploratory research involving complex relationships among latent constructs. The study examines multiple constructs — energy anxiety, energy precarity, and wellbeing — along with a moderating effect, requiring simultaneous estimation of measurement and structural models. Given the moderate sample size and the use of a newly developed measure (EAI), PLS-SEM is appropriate, as it provides stable estimates without requiring strict assumptions of multivariate normality (Hair et al., 2019). In contrast, covariance-based SEM (CB-SEM) is more suited for theory confirmation with large samples and well-established scales (Ringle et al., 2020). Therefore, PLS-SEM aligns more closely with the study's objective of testing and extending a context-specific framework.

The data were analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM). The analytical procedure followed a two-step approach. First, the measurement model was evaluated by assessing indicator reliability, internal consistency reliability (Cronbach's alpha and composite reliability), convergent validity (average variance extracted, AVE), and discriminant validity using the heterotrait–monotrait ratio (HTMT).

Second, the structural model was assessed to examine the hypothesised relationships between constructs. Path coefficients were estimated, and statistical significance was assessed using bootstrapping. Additional diagnostics, including the coefficient of determination (R^2), effect sizes (f^2), and predictive relevance (Q^2predict), were examined to assess the model's explanatory and predictive performance.

4. Results & Discussion:

4.1 Measurement Model Assessment

A measurement model was estimated to assess the reliability and validity of the constructs. The majority of indicator loadings exceeded the recommended threshold of 0.50 and were statistically significant ($p < 0.01$), indicating that the observed variables adequately explained variance in their respective latent constructs (Hair et al., 2019). As shown in Table 2, all standardised factor loadings exceeded 0.70, demonstrating strong indicator reliability.

Common method bias was assessed using two complementary procedures. First, Harman's single-factor test was applied; the first unrotated factor accounted for 39% of total variance, below the 50% threshold (Podsakoff et al., 2003). Second, and more rigorously, a full collinearity assessment was conducted following Kock (2015), in which all construct-level

VIF (Variance Inflation Factor) values were examined for inflation attributable to common method variance. All VIF values fell well below the conservative threshold of 3.3, providing stronger evidence that common method bias does not substantially distort the reported relationships. Together, these two diagnostics offer converging support for the validity of the findings.

The model Standardised Root Mean Square Residual (SRMR) was 0.06, confirming acceptable model fit (Henseler et al., 2015). Internal consistency reliability was established using Cronbach's alpha and Composite Reliability (CR). All constructs demonstrated acceptable reliability, with Cronbach's alpha values and CR values exceeding the recommended threshold of 0.70 (Hair et al., 2019). Average Variance Extracted (AVE) values for all constructs exceeded the minimum criterion of 0.50, demonstrating adequate convergent validity.

Discriminant validity was assessed using the HTMT ratio of correlations. As presented in Table 3, all HTMT values were below the conservative threshold of 0.85 (Henseler et al., 2015). Together, these results indicate that the measurement model exhibits acceptable reliability and validity, supporting its suitability for subsequent structural model analysis.

All constructs are modelled as reflective, as indicators are conceptualised as manifestations of an underlying latent variable and are expected to co-vary (Hair et al., 2019). The EAI is specified as a reflective higher-order construct with reflective first-order dimensions, consistent with its conceptualisation as a unified psychological appraisal. Similarly, energy precarity is treated as reflective, as its indicators represent observable outcomes of an underlying condition of structural energy instability rather than independent formative components.

Table 2: Factor loadings, VIF, CR, and AVE of the lower-order construct

Constructs	Items code	Item Label	Factor loadings	VIF	Cronbach alpha	CR	AVE
Affordability Anxiety	AA1	Electricity affordability	0.843	1.749	0.788	0.798	0.702
	AA2	Energy cost pressure	0.87	1.758			
	AA3	Payment stress	0.8	1.525			
Future Anxiety	FA1	Future concern	0.83	1.566	0.778	0.778	0.692
	FA2	Future uncertainty	0.83	1.618			
	FA3	Energy insecurity	0.835	1.635			
Reliability Anxiety	RA1	Power disruption	0.851	1.727	0.812	0.813	0.727
	RA2	Supply unpredictability	0.852	1.856			
	RA3	Availability uncertainty	0.854	1.775			
Safety Anxiety	SA1	Energy safety	0.825	1.614	0.786	0.789	0.7
	SA2	Fuel risk	0.864	1.762			
	SA3	Safety stress	0.821	1.591			
Energy Precarity	EP1	Unplanned outages	0.786	1.783	0.855	0.857	0.633
	EP2	Activity disruption	0.789	1.784			
	EP3	Voltage fluctuation	0.789	1.827			
	EP4	Energy access constraints	0.774	1.681			

	EP5	Energy use conditions	0.839	2.083			
Life Satisfaction	LS1	Ideal life	0.864	2.471	0.889	0.891	0.694
	LS2	Life conditions	0.804	1.967			
	LS3	Life satisfaction	0.832	2.158			
	LS4	Goal attainment	0.813	1.992			
	LS5	Life contentment	0.849	2.304			
Negative Affect	SN1	Negative affect	0.782	1.729	0.845	0.846	0.617
	SN2	Bad feeling	0.799	1.824			
	SN3	Unpleasant feeling	0.776	1.709			
	SN4	Sadness	0.778	1.729			
	SN5	Fear	0.794	1.76			
Positive Affect	SP1	Positive affect	0.823	2.043	0.876	0.876	0.669
	SP2	Good feeling	0.816	2.049			
	SP3	Pleasant feeling	0.787	1.774			
	SP4	Happiness	0.824	2.084			
	SP5	Contentment	0.838	2.219			

Source: Calculated based on the primary data

Table 3: HTMT Ratio for lower-order construct

	EA	**EP**	**LS**	**SN**	**SP**	**EP x EA**
EA						
EP	0.687					
LS	0.691	0.761				
SN	0.722	0.766	0.868			
SP	0.655	0.721	0.832	0.896		
EP x EA	0.021	0.042	0.166	0.127	0.162	

Source: Calculated based on the primary data

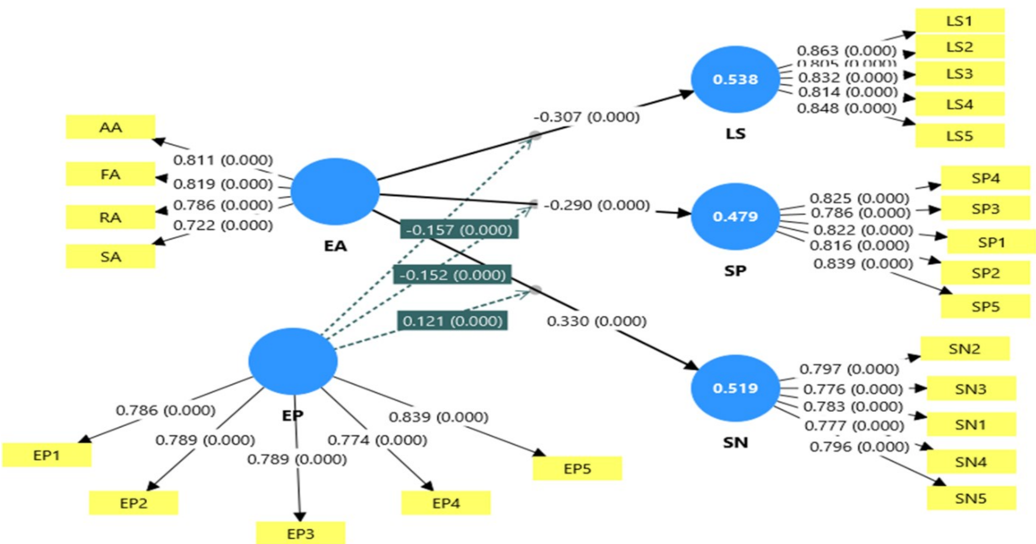

Figure 2. Structural model assessment

4.2 Structural Model Assessment

Following confirmation of the measurement model, the structural model was evaluated using PLS-SEM with bootstrapping (10,000 resamples) to test the hypothesised direct and moderating relationships. The predictive relevance of the model was assessed, and Q^2 values were obtained through blindfolding. All Q^2 values exceeded zero, indicating the model's predictive relevance for the endogenous constructs (Hair et al., 2019). The explanatory power of the structural model was assessed using the coefficient of determination (R^2). The model explained 53.8% of the variance in life satisfaction, 51.9% of the variance in negative affect, and 47.9% of the variance in positive affect, indicating moderate explanatory power for the endogenous constructs.

Effect sizes (f^2) were examined to assess the relative contribution of each predictor variable to the endogenous constructs (Cohen, 1988). Energy precarity demonstrated a large effect on life satisfaction ($f^2 = 0.358$) and moderate effects on negative affect ($f^2 = 0.309$) and positive affect ($f^2 = 0.281$). Energy anxiety exhibited small to moderate effects across the wellbeing dimensions.

As shown in Table 4 and Figure 2, the results of the structural model estimated using PLS-SEM are presented. Energy anxiety exhibited a significant negative association with life satisfaction ($\beta = -0.307$, $p < 0.001$) and positive affect ($\beta = -0.290$, $p < 0.001$), and a significant positive association with negative affect ($\beta = 0.330$, $p < 0.001$). These findings provide support for hypotheses H1a, H1b, and H1c, indicating that higher levels of energy-related worry are associated with poorer cognitive and affective wellbeing outcomes.

Table 4. Structural Model Results: Path Coefficients and Significance

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
EA -> LS	-0.307	-0.311	0.045	6.786	0.0000
EA -> SN	0.33	0.333	0.04	8.335	0.0000
EA -> SP	-0.29	-0.295	0.045	6.415	0.0000
EP -> LS	-0.496	-0.493	0.043	11.434	0.0000
EP -> SN	0.47	0.469	0.041	11.443	0.0000
EP -> SP	-0.466	-0.464	0.046	10.194	0.0000
EP x EA -> LS	-0.157	-0.157	0.031	5.121	0.0000
EP x EA -> SN	0.121	0.121	0.027	4.483	0.0000
EP x EA -> SP	-0.152	-0.151	0.034	4.453	0.0000

Source: Calculated based on the primary data

Energy precarity also demonstrated strong, statistically significant direct effects on subjective wellbeing. Higher energy precarity was associated with lower life satisfaction ($\beta = -0.496$, $p < 0.001$), lower positive affect ($\beta = -0.466$, $p < 0.001$), and higher negative affect ($\beta = 0.470$, $p < 0.001$). The magnitude of these coefficients suggests that structural instability in household energy access exerts a substantial independent influence on wellbeing, supporting hypotheses H2a, H2b, and H2c.

Moderation analysis further indicated that energy precarity significantly moderated the relationship between energy anxiety and all three wellbeing outcomes. The interaction between energy anxiety and energy precarity was negatively associated with life satisfaction ($\beta = -0.157$, $p < 0.001$) and positive affect ($\beta = -0.152$, $p < 0.001$), and positively associated with negative affect ($\beta = 0.121$, $p < 0.001$). These results support hypotheses H3a, H3b, and H3c, indicating that the adverse effects of energy anxiety on subjective wellbeing are stronger under conditions of greater energy precarity.

5. Discussion

The results provide clear empirical evidence that both energy anxiety and energy precarity are significant determinants of subjective wellbeing, with distinct but interrelated effects. Energy anxiety exhibited moderate but statistically significant associations with all wellbeing outcomes. Specifically, higher energy anxiety was associated with lower life satisfaction ($\beta = -0.307$) and lower positive affect ($\beta = -0.290$), alongside higher negative affect ($\beta = 0.330$). The relative strength of the association with negative affect suggests that energy anxiety is more strongly linked to emotional distress and adverse affective states than to global cognitive evaluations of life. This pattern is consistent with the conceptualisation of energy anxiety as a persistent, anticipatory stressor, primarily influencing day-to-day emotional experiences rather than only long-term life assessments (Hernández et al., 2016).At the sub-construct level, the four dimensions of the EAI — affordability anxiety, reliability anxiety, safety anxiety, and future security anxiety — each demonstrated strong and consistent factor loadings, confirming that energy-related psychological stress is multidimensional rather than a unitary experience. The convergence of all four dimensions into a coherent higher-order construct suggests that households do not compartmentalise their energy-related worries; rather, concerns about costs, supply disruptions, safety risks, and future uncertainty operate as an integrated psychological burden. This finding reinforces the case for a domain-specific instrument such as the EAI over single-item or general distress measures, which would fail to capture this dimensionality.

Energy precarity demonstrated substantially stronger direct effects on subjective wellbeing than energy anxiety across all outcomes. The negative association between energy precarity and life satisfaction ($\beta = -0.496$) and positive affect ($\beta = -0.466$), together with its strong positive association with negative affect ($\beta = 0.470$), indicates that structural instability in energy access exerts a more pronounced and pervasive impact on health and wellbeing (Bentley et al., 2023). The larger magnitude of these coefficients suggests that exposure to unreliable, unsafe, and inadequate energy systems directly constrains wellbeing, independent of psychological worry. Empirically, this finding highlights that structural energy conditions are not merely background factors but central determinants of wellbeing outcomes.

The moderation results further clarify the interaction between psychological and structural dimensions of energy insecurity. The interaction term between energy anxiety and energy precarity was statistically significant for all wellbeing outcomes, with negative interaction effects on life satisfaction ($\beta = -0.157$) and positive affect ($\beta = -0.152$), and a positive interaction effect on negative affect ($\beta = 0.121$). Although smaller in magnitude than the main effects, these interaction coefficients are substantively meaningful, indicating that the adverse effects of energy anxiety are amplified under conditions of higher energy precarity (Petrova, 2018). This implies that energy-related worry becomes more damaging to wellbeing when households face unstable or inadequate energy services, reflecting reduced coping capacity and heightened exposure to risk.

Comparing the main and interaction effects suggests an important hierarchy of influence. While energy anxiety independently affects wellbeing, its impact is conditioned by structural energy precarity, which both directly undermines wellbeing and intensifies the psychological burden of energy-related worry. The stronger direct effects of energy precarity indicate that improvements in structural energy stability may yield larger wellbeing gains than interventions targeting psychological distress alone.

From a field perspective, these findings are consistent with rural energy contexts where households experience formal electrification alongside persistent issues of unreliable supply, unsafe cooking fuels, and limited alternatives. In such settings, structural instability appears to dominate wellbeing outcomes, while psychological anxiety compounds these effects rather than replacing them. The results, therefore, underscore the importance of analytically separating energy anxiety from energy precarity, while recognising their combined influence on subjective wellbeing.

This study makes a theoretical contribution by grounding the conceptualisation and measurement of energy anxiety within Conservation of Resources Theory (Hobfoll, 1989) and the Stress Process Model (Pearlin et al., 1981). The EAI operationalises the psychological appraisal of resource threat — specifically, the persistent worry arising from chronic instability in a resource as fundamental as energy — rather than the material fact of deprivation itself. In contrast to existing energy insecurity scales, which primarily capture behavioural or circumstantial indicators of deprivation, the EAI measures the subjective psychological experience of living under conditions of energy uncertainty. The moderation findings further validate the resource loss spiral mechanism: structural precarity depletes household coping capacity, amplifying the wellbeing consequences of energy-related worry. Together, these contributions offer a theoretically integrated and empirically validated framework for understanding the psychological pathways through which energy poverty affects wellbeing in marginalised rural contexts.

The findings have several implications for energy policy and welfare interventions aimed at improving wellbeing in rural and marginalised contexts. First, the significant associations between energy anxiety and all dimensions of subjective wellbeing suggest that energy poverty interventions should extend beyond physical access and affordability to address the psychological consequences of insecure energy conditions. Policies that reduce uncertainty—such as predictable supply schedules, transparent billing practices, and reliable grievance mechanisms—may help alleviate energy-related worry even in the absence of immediate infrastructure upgrades. Second, strengthening last-mile operation and maintenance systems is critical for improving service reliability, particularly in low-income or rural areas where technical faults often remain unresolved for extended periods. Third, targeted programmes that address the financial barriers associated with household energy access are particularly important. Policy interventions such as subsidised energy tariffs, flexible payment mechanisms, micro-finance support, or targeted subsidies for clean energy technologies can reduce the economic burden on low-income households.

5.1 Limitations

The findings should be interpreted with several limitations. First, the cross-sectional design precludes causal inference. While the hypothesised direction of effects is theoretically grounded, longitudinal research is needed to establish temporal ordering and examine how changes in energy conditions translate into wellbeing outcomes over time. Second, the study employed purposive cluster sampling within a single area, targeting villages with high levels of energy deprivation. While this enabled a focused examination of severe energy insecurity, the criterion-based selection means the findings may not fully generalise to populations with moderate energy access. Additionally, the focus on specific socio-demographic groups may limit transferability to regions with different infrastructural and social contexts. Accordingly, the results should be interpreted as context-specific insights rather than population-level estimates. Future research should adopt stratified random sampling across multiple regions to enhance generalisability. Third, the reliance on self-report measures introduces potential reporting biases. Future studies could complement self-reports with qualitative findings to provide additional insights. Additionally, the study did not incorporate demographic controls or conduct multigroup analyses by energy typology — such as self-reliant versus electrified households — due to constraints of sample size and study design; future research with larger stratified samples should address these analytical extensions.

6. Conclusion

This study examined the relationships among energy anxiety, energy precarity, and subjective wellbeing among rural households in Baripada district, Odisha. The findings show that energy anxiety is significantly associated with lower life satisfaction and positive affect, and higher negative affect, while energy precarity exerts stronger direct effects across all wellbeing outcomes. The moderation results further demonstrate that energy precarity amplifies the adverse effects of energy anxiety on subjective wellbeing, highlighting the combined influence of psychological responses and structural energy instability. By distinguishing between energy anxiety and energy precarity, the study offers a more nuanced understanding of how energy poverty affects wellbeing in rural and marginalised contexts.

The findings should be interpreted in light of certain limitations, including the cross-sectional design and the geographic focus on a single district, which restricts causal inference and broader generalisation. Future research should extend this framework to other settings, adopt longitudinal designs, and further validate the Energy Anxiety Index to examine how changes in energy conditions translate into wellbeing outcomes over time.

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Appendix

Table 5: Factor loadings and Item description

Constructs	Item code	Items	Factor loadings	VIF
Affordability Anxiety	AA1	I often worry that my electricity bill will be more than I can afford.	0.843	1.749
	AA2	Rising energy costs make me anxious about managing household expenses.	0.87	1.758
	AA3	I feel stressed thinking about how to pay for energy every month.	0.8	1.525
Future Anxiety	FA1	I worry about whether my household will have reliable energy in the future.	0.83	1.566
	FA2	Thinking about future energy availability makes me anxious.	0.83	1.618
	FA3	I feel uncertain and worried about long-term energy security for my family.	0.835	1.635
Reliability Anxiety	RA1	I worry about sudden power cuts affecting my daily activities.	0.851	1.727
	RA2	Unpredictable electricity supply makes me feel tense or frustrated.	0.852	1.856
	RA3	I am anxious that electricity may not be available when it is most needed.	0.854	1.775

Safety Anxiety	SA1	I feel unsafe using certain energy sources in my household.	0.825	1.614
	SA2	I worry about accidents or health problems related to lighting fuel use.	0.864	1.762
	SA3	Concerns about energy safety create stress in my daily life.	0.821	1.591
Energy Precarity	EP1	My household experiences frequent interruptions in electricity supply.	0.786	1.783
	EP2	I find it difficult to maintain adequate energy for daily household needs.	0.789	1.784
	EP3	The quality of electricity (e.g., voltage fluctuations) is often poor.	0.789	1.827
	EP4	My household depends on fuels that are unsafe or harmful.	0.774	1.681
	EP5	I have limited alternatives when my primary energy source fails.	0.839	2.083
Life Satisfaction	LS1	In most ways, my life is close to my ideal.	0.864	2.471
	LS2	The conditions of my life are excellent.	0.804	1.967
	LS3	I am satisfied with my life.	0.832	2.158
	LS4	So far, I have gotten the important things I want in life.	0.813	1.992
	LS5	If I could live my life over, I would change almost nothing.	0.849	2.304
Negative Affect	SN1	I felt negative	0.782	1.729
	SN2	I felt bad	0.799	1.824
	SN3	I felt unpleasant	0.776	1.709
	SN4	I felt sad	0.778	1.729
	SN5	I felt afraid	0.794	1.76
Positive Affect	SP1	I felt positive	0.823	2.043
	SP2	I felt good	0.816	2.049
	SP3	I felt pleasant	0.787	1.774
	SP4	I felt happy	0.824	2.084
	SP5	I felt contented	0.838	2.219