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# Income-driven behavioral heterogeneity in rural energy transition: a TPB analysis of China's coal-to-electricity policy

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To address air pollution and advance clean energy adoption, China's "coal-to-electricity" policy has encountered varied compliance among farmers due to income disparities. Integrating the Theory of Planned Behavior with income stratification, this study examines rural households' behavioral intentions in Pu County, Shanxi, using structural equation modeling on survey data from 221 households. Results show distinct drivers across income groups: low-income farmers rely heavily on perceived behavioral control ( $\beta = 0.396$ ,  $p < 0.01$ ), emphasizing financial constraints; middle-income farmers balance policy trust and environmental awareness; and high-income farmers respond strongly to subjective norms ( $\beta = 0.760$ ,  $p < 0.01$ ), reflecting social influence. These findings argue against a uniform subsidy approach and propose tailored strategies—direct financial support for low-income groups, technical incentives for middle-income farmers, and normative interventions for high-income adopters—offering behaviorally-informed policy insights for advancing SDG 7 and SDG 13 in developing countries.

## KEYWORDS

behavioral willingness, coal-to-electricity policy, income heterogeneity, structural equation modeling, subsidy strategies, theory of planned behavior (TPB), sdgs

## 1 Introduction

Similar to how the emergence, development, and commercialization of industrial technologies follow their own inherent laws, the evolution of energy systems also adheres to its own patterns (Li et al., 2023). This transformation is a systematic and dynamic process, driven both by advancements in energy technology and the pull of demand-side developments. In this regard, the rapid development of China's rural industry has drastically increased energy consumption and demand in rural areas, where the energy consumption structure is transitioning from traditional biomass energy to commercial energy. In China, coal is the primary source of commercial energy (Zhang et al., 2009). In light of the increasing rate of energy utilization in industries and governmental regulations on industries with high energy consumption and high pollutant emissions, the growth in energy demands and carbon emissions in rural areas is primarily due to household energy consumption (Balances and Countries, 2010). Many scholars have opined that China's predominant coal-based energy consumption structure is the main source of haze in the country. Advancing technological innovation, adopting cleaner alternative energy

sources, and transforming the energy mix are fundamental solutions to mitigating haze (Weixian and Ma, 2015; He, 2015; Ma et al., 2016). In response, regional governments in China have in recent years been advocating policies pertaining to energy upgrades (such as the “coal-to-electricity” and the “coal-to-gas” policies) with the aim of improving China’s air quality.

From the perspectives of economic growth theory and technological evolution theory, the transformation of energy systems constitutes a systematic and dynamic evolutionary process, driven both by energy technology innovation and demand-side development (Li et al., 2023). The energy ladder hypothesis (Leach, 1992) and the fuel stacking hypothesis are two major theories regarding energy transition. According to the energy ladder hypothesis (Barnes et al., 1996), a household’s energy consumption will shift from low-quality to high-quality energy consumption patterns as a result of socioeconomic development. Leach (Leach, 1992) summarized the process of energy transition and defined it as an individual consumer’s shift from biomass-based energy sources to modern energy sources. The energy ladder hypothesis states that household energy consumption patterns shift from low-quality to high-quality fuels through three steps: using traditional biomass fuels such as wood fuel; using transition fuels such as coal and liquefied petroleum gas; and using cleaner fuels such as electricity and natural gas. Residents upgrade their energy consumption patterns on their own initiative; when one’s standard of living reaches a certain level, one will prefer energy sources that are more comfortable, convenient, and clean (Zhao, 2015). According to the fuel stacking hypothesis (Jiang et al., 2004; Nansaior et al., 2011), the upgrading of energy consumption patterns is not a linear, unidirectional, or natural process in which households switch from low-quality to high-quality fuels. Instead, households maximize their energy consumption efficiency by simultaneously consuming multiple types of fuel (Masera and Navia, 1997). In reality, the simultaneous utilization of multiple fuels within the same household is rather ubiquitous. Masera and Navia (Farsi et al., 2007) suggested that two opposing sets of factors that influence energy utilization among humans. A push factor drives humans to use new, efficient, and clean energy sources, while a pull factor urges humans to maintain their original lifestyles and retain their use of traditional energy sources. Therefore, the growing number of fuel types simultaneously used among humans is known as the fuel stacking model. The energy ladder models and the fuel stacking models illuminate the link between transitions in energy consumption and economic developments, especially in response to growth in income. This shows that the energy ladder model and the fuel stacking model both emphasize that in terms of energy transitions based on farmer autonomy, household income is an important factor as well as the main driving force of transitions in energy consumption patterns (Jiang et al., 2004; Farsi et al., 2007; Sheinbaum et al., 1996).

However, increasing household income constitutes a long-term endeavor that cannot yield immediate results. Concurrently, energy transition presents households with multiple consumption choices influenced by personal preferences, rendering it a complex, protracted process (Smil, 2010). When governments mandate passive energy transitions among farmers, appropriate subsidies must be implemented to enhance willingness for consumption pattern upgrades. While mainstream economics typically attributes energy transition choices to economic rationality

(van der Kroon et al., 2013), this perspective neglects the critical role of subjective psychological factors (Ai et al., 2021). The observed phenomenon of fuel stacking during energy transitions embodies both economic and social behaviors (Armitage and Conner, 2001). Consequently, framing energy transition solely through the economic lens of income-driven consumption shifts proves inadequate for this socio-environmental challenge, as it disregards households’ agency in moral and social responsibility considerations. In the case of the coal-to-electricity policy, since the government implements an indiscriminate subsidy policy and does not take into account the farmers’ psychological factors, farmers are less willing to comply with the policy. In addition, farmers’ willingness to undergo energy transition are also affected by their demographic characteristics, such as gender (Schahn and Holzer, 1990); education level (Kwayu et al., 2014); residence (Wang and Yin, 2010), marital status and health status (Xu, 2018), and motivations for pursuing good health (Shi, 2015). Lack of consideration of these factors limits policymakers’ ability to tailor interventions to diverse socioeconomic groups. The theory of planned behavior (TPB), originated from a multi-attribute and dynamic theory proposed by Fishbein (1963), which states that object is shaped by behavioral attitudes, while behavioral attitude is shaped by expected outcomes and outcome evaluation. On this basis, Ajzen and Fishbein (1973) proposed the theory of reasoned action, which suggests that a person’s behaviors can be guided by their behavioral intentions, which, in turn, is influenced by their attitudes and the perceived normative expectations. To this end, Ajzen (Icek, 1991) revised the theory of reasoned action by adding a person’s perceived control over their behaviors (perceived behavioral control) as a factor that influences intentions. Farmers’ willingness is determined by various psychological indicators such as personal attitude, subjective norms, and perceived behavioral control. The TPB offers a high explanatory power for human behaviors that are rational and cannot be fully controlled by self-will. It has been widely applied in studies pertaining to human behaviors in various fields, as such the influence of water conservation awareness on water-conserving irrigation behavior (Zhong et al., 2019), the influence of transfer of grassland use rights on grassland protection awareness (Li et al., 2018), and rural households’ willingness to pay for retrofitting rooftops with solar photovoltaic tiles to promote the Green and low-carbon energy transition (Tan et al., 2023). These studies have indeed produced extremely valuable results.

Existing studies employing single-equation approaches including fixed-effects models and logistic regression for energy transition analysis demonstrates significant constraints (Burke, 2013; Kopsakangas-Savolainen and Juutinen, 2013; Liao et al., 2019; Choumert-Nkolo et al., 2019). These methods primarily examine the one-directional relationship between economic determinants like household income and energy consumption patterns, while neglecting the combined influence of psychosocial elements such as subjective attitudes, perceived behavioral control, and subjective norms. Additionally, such methodologies cannot adequately account for endogeneity issues among interrelated variables or represent intricate causal pathways. Structural equation modeling (SEM) offers a robust alternative by permitting the concurrent estimation of multiple equations, incorporating both unobserved constructs like ethical obligations and community standards along with measurable

variables including income levels. This analytical technique allows for evaluation of direct impacts as well as indirect mediated relationships, such as how income might shape behavioral intentions through its effect on perceived control. Such an approach yields deeper insights into the psychological processes driving energy transition decisions, consistent with the attitude-intention-behavior paradigm central to behavioral theory. The methodology further enables comparative analysis across socioeconomic subgroups, such as differentiated farmer categories, thus overcoming the systemic and dynamic analytical deficiencies inherent in conventional single-equation models.

This study integrates Ajzen's Theory of Planned Behavior (TPB) with income stratification to propose a novel analytical framework for examining the formation mechanisms of farmers' willingness to adopt energy transition under China's coal-to-electricity policy. A structural equation model (SEM) is employed to explore the mechanisms influencing farmers' willingness to transition, while an ordered logistic regression is used to analyze the impact of farmers' demographic characteristics on their willingness. The TPB posits that behavioral intentions are shaped by three dimensions: subjective attitudes (personal evaluations), subjective norms (social pressures), and perceived behavioral control (self-efficacy). By classifying farmers into low-, middle-, and high-income groups, we investigated two core questions (Li et al., 2023): How do TPB variables differentially influence the willingness of farmers across income groups (Zhang et al., 2009)? What policy adjustments can enhance compliance while addressing income-based disparities?

Our analysis, based on survey data from 221 households from Pu County, Shanxi Province, revealed significant heterogeneity. For low-income farmers, subjective attitudes and perceived control were pivotal, whereas high-income groups were primarily influenced by subjective norms. Middle-income farmers exhibited a hybrid pattern, with perceived control dominating their decisions. These findings challenge the conventional "one-size-fits-all" subsidy approach and highlight the need for income-targeted interventions.

This study contributes to the literature by (Li et al., 2023): Extending the TPB framework to policy-driven energy transitions, emphasizing income as a moderating variable (Zhang et al., 2009). Providing empirical evidence on the psychological barriers to energy transition in rural China (Balances and Countries, 2010). Offering actionable recommendations for designing stratified subsidy policies.

The remainder of this paper is organized as follows: Section 2 outlines the theoretical framework, Section 3 describes the methodology and materials used in the analysis, Section 4 presents the results, Section 5 discusses implications, and Section 6 concludes with policy recommendations.

## 2 Theoretical framework

### 2.1 Theoretical basis

The three major variables that influence a person's willingness are subjective attitudes, perceived behavioral control, and subjective norms (Bagozzi et al., 2001; Clark and Wang, 2003). Therefore, with regard to the implementation of the coal-to-electricity policy, we divided farmers' willingness into three dimensions - subjective

attitudes, perceived behavioral control, and subjective norms. According to the energy ladder hypothesis, residents' process of energy transition is closely associated with their income level. In order to examine the differences between the willingness of farmers in different income groups to choose passive energy transition, we classified the farmers into high-income, middle-income, and low-income groups. Next, we investigated the factors affecting the development of their willingness as well as the differences in the paths forming their willingness, so as to provide more precise evidence for policy implementation.

### 2.2 Research hypotheses

Subjective attitude refers to a person's positive or negative feedback toward a specific behavior. Wang (Wang et al., 2015) demonstrated that subjective attitude is the main factor influencing farmers' behavioral willingness. The survey by Postmes and Brunsting (2002) revealed that the attitudes of participants in environmental activities significantly affect their behavioral willingness (Postmes and Brunsting, 2002). Hu et al. (2014) suggested that attitude is the main factor that determines whether people would engage in low-carbon tourism and also shapes their willingness to engage in this form of tourism (Hu et al., 2014). Pennings and Leuthold (2000), Sun and Yu (2012) validated that farmers' behavioral attitudes promote their willingness to engage in contract farming (Pennings and Leuthold, 2000; Sun and Yu, 2012). In this study, subjective attitude refers to the proactive or passive attitudes of farmers to comply with the coal-to-electricity policy. When farmers perceive that the coal-to-electricity policy would improve the living condition of their family; protect the local ecology; and provide a better environment for their offspring, they would display a proactive attitude toward the policy and have a tendency to alter their willingness. Discrepancies in farmers' income levels also cause their subjective attitude to influence their willingness to varying degrees.

Therefore, this study proposed Hypothesis 1 as follows: The subjective attitudes of farmers in different income groups have varying degrees of influence on their willingness to comply with the coal-to-electricity policy.

Perceived behavioral control refers to a person's perception of their ability to perform a certain behavior (Zhong et al., 2019), that is, the farmers' perceived degree of control over the implementation of the coal-to-electricity policy. Farmers' control consists of an internal and an external component. Internal control refers to the farmers' competence in terms of their intrinsic physical capabilities, knowledge, and skills that correspond to a certain behavior, such as their perceived ability to bear the upfront costs of coal-to-electricity conversion. External control refers to extrinsic opportunities and resources (Tan et al., 2023), such as trust in government subsidies or technical support. Xie and Chen (2019) pointed out that perceived behavioral control significantly and positively affects farmers' willingness to earn a living, and elevating farmers' perceived behavioral control is an important means of elevating their willingness. In this study, perceived behavioral control includes the farmers' perceptions of the development, governance measures, and funding conditions of the coal-to-electricity policy. In other words, perceived behavioral control refers

to farmers' evaluation of their abilities which may promote or inhibit their behavior. When farmers perceive a stronger ability to control their behavior, they feel less pressurized to comply policy-wise, and would exhibit a more proactive response toward the policy. Since all three income groups have different perceived behavioral control, the degree of influence on their willingness varies as well.

Therefore, this study proposed Hypothesis 2 as follows: The perceived behavioral control of farmers in different income groups have varying degrees of influence on their willingness to comply with the coal-to-electricity policy.

Subjective norms refer to the effect of residents' social environment which directs their behavioral willingness. Subjective norms consist of prescriptive norms and demonstrative norms (Cialdini et al., 1991). Prescriptive norms are mainly derived from government officials, who have strong leadership and impetus and have an important influence on farmers' decision-making. For example, policy advocacy by grassroots officials and punitive measures (such as regulations in coal-free zones) reflect farmers' perception of external pressure to "comply with mandates." Demonstrative norms are mainly derived from the farmers' neighbors, relatives, and friends (Wan et al., 2017), reflecting their need for social conformity—the perception that they should comply to align with peer expectations." A multitude of studies pertaining to farmers' behavioral willingness, such as the willingness of rural households to purchase home appliances (Wu et al., 2010); willingness to engage in agricultural safety production (Du et al., 2014); and willingness to engage in health and wellbeing tourism (Xie et al., 2019) have indicated that subjective norms affect farmers' willingness. In this study, subjective norms refer to the potential impetus exerted by relatives and neighbors or government officials on farmers during the implementation of the coal-to-electricity policy. Since all three income groups have their own specific social resources, the degree of the influence of subjective norms on their willingness varies as well: High-income groups are more influenced by demonstrative norms, while low-income groups tend to rely more on prescriptive norms.

Therefore, this study proposed Hypothesis 3 as follows: The subjective norms of farmers from different income groups have varying degrees of influence on their willingness to comply with the coal-to-electricity policy.

In addition to the influence of "soft" indicators such as subjective attitude, subjective norms, and perceived stress of policy compliance on farmers' willingness, we also included farmers' basic demographic characteristics (age, gender, family size, and education level) into our study.

Therefore, this study proposed Hypothesis 4 as follows: Farmers' demographic characteristics are an important factor affecting their willingness to comply with the coal-to-electricity policy.

## 3 Methodology and materials

### 3.1 Research area

Pu County is located in southeastern Shanxi Province and south of Lüliang Mountain, China. Its coordinates are approximately 36.38° ~ 36.62° latitudinally and 110.92° ~ 111.38° longitudinally. It has a mean annual temperature of 8.7 °C and receives 586 mm

of rainfall annually. Pu County is blessed with mineral resources, especially coal, with around 18.17 billion tons of reserves covering an area of 1,360 km<sup>2</sup>. There were 110,810 permanent residents living in the county, with Han Chinese accounting for a majority of the population. In December 2018, the Pu County Government promulgated the "Pu County Three-year Action Plan to Fight Air Pollution," which states that coal for domestic use must be substituted by cleaner fuels. The plan also strengthens the designation of "coal-free zones" and aims to transition to cleaner energy sources, such as from coal to electricity and from coal to gas. In "coal-free zones," the storage, sales, and use of coal is banned, except for coal-fired electricity generators, large-scale heat providers, and companies that use coal as a raw material.

### 3.2 Data sources

From July to August 2019, our team conducted a 53-day field survey in Pu County, Shanxi Province. Data was collected by means of the participatory rural appraisal (PRA) approach (Chambers, 1994; Cramb et al., 2004); questionnaire administration; and examining the region's socioeconomic statistics. We conducted the survey through stratified random sampling across all eight townships in Pu County, administering questionnaires to 230 selected rural households. To better capture resistance factors, we deliberately oversampled coal-rich areas (36% of samples versus their 28% county-wide population share) while maintaining proportional representation of transitional (40%) and non-coal (24%) zones - a sampling strategy rigorously validated against the 2019 County Statistical Bulletin. A total of 221 valid responses were collected, indicating an effective response rate of 96.09%. Since the unit of energy consumption is per household, we used the classification method developed by Chen (2010) and Chang et al. (2020), in which farmers were classified into three groups based on their income (Chen, 2010; Chang et al., 2020). Based on the 2019 Shanxi provincial income data (rural *per capita* disposable income of 12,902 yuan and urban *per capita* disposable income of 33,262 yuan) and following the classification methodology of the 2020 China Rural Statistical Yearbook, we established a three-tier income classification system for rural households: (Li et al., 2023): Low-income households (annual income ≤30,000 yuan), representing approximately 2.3 times the rural *per capita* disposable income and slightly above the rural subsistence allowance standard (4,953 yuan/year) (Zhang et al., 2009); Middle-income households (30,000–60,000 yuan/year), corresponding to about 2.3–4.7 times the rural baseline; and (Balances and Countries, 2010) High-income households (≥60,000 yuan/year), exceeding 1.8 times the urban *per capita* income level. This classification scheme accounts for both absolute income thresholds and relative purchasing power differences between rural and urban areas, while maintaining consistency with national statistical standards and local policy implementation requirements for the coal-to-electricity transition program. The questionnaire items covered the farmers' basic information as well as four dimensions. There were four measured variables pertaining to subjective attitude; three variables pertaining to subjective norms; three variables pertaining to perceived behavioral control; and two variables pertaining to behavioral willingness. The questionnaire responses were quantified

on a five-point Likert scale (Likert, 1932). Table 1 provides a detailed description of the questionnaire design.

### 3.3 Model construction

Based on the theory of planned behavior and by conducting field surveys, we established indicators that correspond to the three dimensions of subjective attitude, subjective norms, and perceived behavioral control. The meanings of the indicators are presented in Table 1.

Structural equation modeling is a statistical approach that combines factor analysis and path analysis. Variables that cannot be measured directly, such as subjective attitude and behavioral willingness are called latent variables; variables that reflect these latent variables are called observed variables. Structural equation models (SEM) can effectively analyze the relationships and paths between latent variables and observed variables. An integrated model that explains the factors that affect farmers' willingness to comply with the coal-to-electricity policy is depicted in Figure 1. In this study, the SPSS22.0 statistical software was used to test the reliability and validity of the questionnaire. Data analysis was additionally performed using AMOS21.0 software.

### 3.4 Sample characteristics

This study employed SPSS22.0 software to analyze the respondents' basic information such as gender, age, education level, and family size. 75.1% of the respondents were male while 24.9% were female. 22.2% of the respondents were aged 35 years and below; 64.7% were aged between 36 and 55 years, which accounted for a majority of the respondents; while 13.1% were aged above 56 years. In general, the education level of the sampled respondents was low. A majority (39.8%) of the respondents only received junior high school education, while 23.5% of the respondents only received elementary school education and below. The data is specified in Table 2.

### 3.5 Reliability and validity testing

In this study, the SPSS22.0 statistical software was used to test the reliability and validity of the overall sample. As shown in Table 3, the variables subjective attitude; subjective norms; perceived behavioral control; and behavioral willingness had passed the reliability test. The Cronbach's  $\alpha$  is often used as an indicator of questionnaire reliability. All the questionnaire items in this study had a Cronbach's  $\alpha$  exceeding 0.8 (in which  $\geq 0.8$  indicates high reliability;  $\geq 0.7$  indicates good reliability;  $> 0.5$  indicates acceptable reliability). In general, the questionnaire had a high reliability. In the exploratory factor analysis, the correlation coefficients between the observed variables were greater than 0.3. The KMO values of the four latent variables were equal or greater than 0.5 and the result of the Bartlett's test of sphericity was significant (0.000, which was smaller than 0.001). The cumulative percentage of variance ranged from 72.814% to 91.477%, and the fact that these figures were higher than 70% indicates a high correlation between the observed variables in each latent variable and the data was consistent, which is suitable

for factor analysis. Therefore, the questionnaire passed the test of validity.

## 4 Results

### 4.1 Parameter estimation

Structural equation modeling (SEM) analysis using AMOS 21.0 revealed distinct patterns across income groups (submitted Supplementary Table SA). For low-income farmers, both subjective attitude ( $\beta = 0.348$ ,  $p < 0.01$ ) and perceived behavioral control ( $\beta = 0.396$ ,  $p < 0.01$ ) exhibited significant positive effects on behavioral willingness, while subjective norms showed a moderate influence ( $\beta = 0.327$ ,  $p < 0.05$ ). Among middle-income farmers, perceived behavioral control dominated ( $\beta = 0.746$ ,  $p < 0.01$ ), whereas subjective attitude had negligible impact ( $\beta = 0.084$ ,  $p < 0.05$ ). Notably, high-income farmers were primarily driven by subjective norms ( $\beta = 0.760$ ,  $p < 0.01$ ), with no significant effects from subjective attitude or perceived control. These results validate Hypotheses 1–3, highlighting income-based heterogeneity in decision-making pathways.

### 4.2 Evaluation of model fit

The SEM demonstrated strong alignment with the data across all income groups (Table 4). Absolute fit indices (CMIN/df  $< 3.0$ , GFI  $> 0.86$ , RMSEA  $< 0.10$ ) and relative fit indices (NFI, TLI, CFI  $> 0.86$ ) met recommended thresholds. Information criteria (AIC, CAIC) further confirmed model robustness.

### 4.3 Path analysis of model

#### 4.3.1 Permission to reuse and copyright

In this study, subjective attitude refers to a farmer's positive or negative feedback on the implementation of the coal-to-electricity policy. The subjective attitude of low-income farmers had a significant effect on their willingness. As shown in Figure 2, the factor loadings of the observed variables pertaining to subjective attitude (environmental awareness, cognitive effect, consciousness of responsibility, and personal attitude) were 0.54, 0.86, 0.79, and 0.91, respectively. This indicates that the environmental consciousness of low-income farmers remains low. This is because when the farmers' income is inadequate to meet their living expenses, they would not pay attention to ecological and environmental conditions. The factor loading of consciousness of responsibility (X3) was greater than 0.7. To a certain extent, this finding indicates that the farmers perceived that the government and society should bear most of the responsibility related to the coal-to-electricity policy. The higher path coefficient between cognitive effect and personal attitude implies that the cognitive effect and personal attitude of low-income farmers are more likely to turn into subjective attitudes. When farmers perceive that electricity is a cleaner and more convenient energy source, they would take the initiative to switch their energy consumption pattern

TABLE 1 Questionnaire on farmers' willingness to comply with the coal-to-electricity policy.

| Dimension                    | Number | Observed variable               | Question                                                                                                                                                                  |
|------------------------------|--------|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Subjective attitude          | X1     | Environmental consciousness     | Are you ashamed of the pollution caused by burning coal?                                                                                                                  |
|                              | X2     | Cognitive effect                | Do you agree with the following statement? - Transitioning from coal to electricity would make my life more convenient and is also a means of protecting the environment. |
|                              | X3     | Consciousness of responsibility | Who do you think should bear the costs of transitioning from coal to electricity?*                                                                                        |
|                              | X4     | Personal attitude               | Have you and your family considered transitioning from traditional coal to electricity?                                                                                   |
| Perceived behavioral control | X5     | Family values                   | Do you agree with the following statement? - My family has made a lot of effort to understand the specific measures and benefits of the coal-to-electricity policy.       |
|                              | X6     | External perception             | Do you agree with the following statement? - I believe the government would provide subsidies for those who transitioned from coal to electricity.                        |
|                              | X7     | Family's ability                | Do you agree with the following statement? - My family is able to cover some of the cost for transitioning from coal to electricity.                                      |
| Subjective norms             | X8     | Social expectations             | Do you agree with the following statement? - Society as a whole is advocating the use of clean energy sources.                                                            |
|                              | X9     | Public expectations             | Do you agree with the following statement? - I am willing to imitate the actions of my neighbors and friends if they all switch to electricity.                           |
|                              | X10    | Government expectations         | Would you proactively participate in the local government's educational activities on the coal-to-electricity policy?                                                     |
| Behavioral willingness       | Y1     | Willingness to participate      | Under the current policy, are you willing to transition from coal to electricity?                                                                                         |
|                              | Y2     | Willingness to invest           | How much money are you willing to pay to transition from coal to electricity?**                                                                                           |

All responses are measured on a five-point Likert scale in which 1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree. \*1 = Fully covered by the government; 2 = Mostly covered by the government; 3 = Equally covered by farmers and the government; 4 = Mostly covered by farmers; 5 = Fully covered by farmers. \*\*1 = Less than RMB1000; 2 = RMB1000~3000; 3 = RMB3000~5000; 4 = RMB5000~7000; 5 = More than RMB7000.

to electricity, and would exhibit a positive attitude toward the coal-to-electricity policy.

According to Table 4, the perceived behavioral control of low-income farmers significantly and positively affects their willingness.

As shown in Figure 2, the three observed variables pertaining to perceived behavioral control had a factor loading of 0.75, 0.81, and 0.84, respectively. The effect of family's ability on perceived behavioral control was the most pronounced. When farmers are

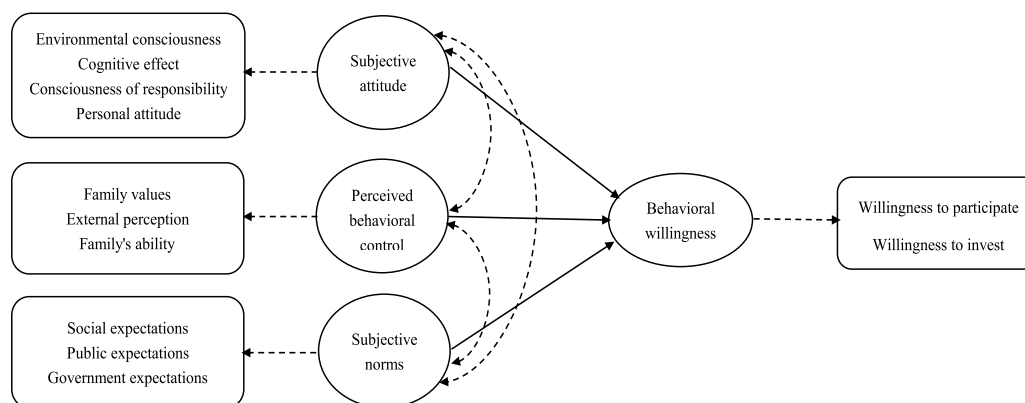


FIGURE 1  
Integrated model of factors affecting farmers' behavioral willingness to comply with the coal-to-electricity policy.

unable to afford transitioning to or using electricity, their perceived behavioral control would decrease, which affects their behavioral willingness. Low-income farmers would only evaluate their ability to comply with the coal-to-electricity policy when they perceive that the government would provide subsidies for implementing the policy.

Subjective norms had a significant effect on the willingness of low-income farmers at a 5% level of significance. In particular, public expectations had a factor loading of 0.78, which suggests that the farmers are more willing to switch to electricity. Due to the influence of traditional Chinese cultural values, when their neighbors and friends have all switched to using electricity, the farmers would consider upgrading to electricity even though they have to undertake higher costs for doing so.

#### 4.3.2 Path analysis of factors affecting the willingness of middle-income farmers

According to the parameter estimation results presented in Table 4, we found that the subjective attitude and perceived behavioral control of middle-income farmers significantly affected their willingness at a 5% and 1% level of significance, respectively. As shown in Figure 3, the path coefficient of the four variables pertaining to subjective attitude was 0.84, 0.58, 0.85, and 0.89, respectively. This shows that environmental consciousness, consciousness of responsibility, and personal attitude can, to a certain extent, influence farmers' behavior. In other words, when farmers have a stronger demand for a good environment, they would change their standpoints to supporting policies that protect the environment. Middle-income farmers would consider switching to electricity on own initiative and express their support for the coal-to-electricity policy. This is because an increase in income would encourage the farmers to become more proactive in pursuing cleaner and more convenient energy sources. However, at the same time, if the government and society have to afford more costs for the transition, the farmers would become more proactive in policy implementation.

Perceived behavioral control is an important factor shaping the development of willingness among middle-income farmers. The factor loading of its related observed variables, namely, family

values, external perception, and family's ability, was 0.99, 0.56, and 0.53, respectively. Compared to low-income farmers, family values have a higher likelihood of transforming into perceived behavioral control among middle-income farmers. This shows that after the farmers had taken some effort to understand the contents and benefits of the coal-to-electricity policy, their ability to control would increase. This is because middle-income rural households are capable of affording some of the costs of transitioning to electricity, and hence, they are able to control their family's ability and external perception to a certain extent. Farmers with a higher understanding of the contents and subsidies of the policy have a higher trust on the policy. This perception would also transform into willingness.

#### 4.3.3 Path analysis of factors affecting the willingness of high-income farmers

The direct path coefficient of subjective norms on the willingness of high-income farmers was 0.76, which was significant at a 1% level of significance, whereas subjective attitude and perceived behavioral control had less effect on their willingness. This implies that for high-income farmers, an increase in subjective norms would increase the likelihood of that they develop willingness. Since these farmers have a higher income level as well as diverse sources of income, if they have enough funds to transition to electricity without compromising their quality of life, then they would have higher demand for energy sources that are more comfortable, convenient, and hygienic. In this regard, they would consider switching to electricity, which is cleaner and more convenient, on their own initiative. Therefore, the effects of subjective attitude and perceived behavioral control on willingness would not change drastically following policy implementation. Due to the influence of group consciousness, subjective norms had a significant effect on behavioral willingness. Group consensus can inhibit a person's behavior through external rewards or stress, especially in rural areas (Campbell et al., 2004). Our field survey also revealed that some high-income farmers had already switched to electricity even before the policy was implemented. While some of them were very supportive of the policy, they have yet to transition to electricity due to the influence of their low and middle-income neighbors and

TABLE 2 Characteristics of respondents in the research area.

| Variable              | Classification                    | Total sample size | Low-income  |                | Middle-income |                | High-income |                |
|-----------------------|-----------------------------------|-------------------|-------------|----------------|---------------|----------------|-------------|----------------|
|                       |                                   |                   | Sample size | Percentage (%) | Sample size   | Percentage (%) | Sample size | Percentage (%) |
| Number of respondents |                                   | 221               | 76          | 34.4           | 75            | 33.9           | 70          | 31.7           |
| Gender                | Male                              | 166               | 61          | 80.3           | 53            | 70.7           | 52          | 74.3           |
|                       | Female                            | 55                | 15          | 19.7           | 22            | 29.3           | 18          | 25.7           |
| Age                   | ≤35                               | 49                | 16          | 21.1           | 23            | 30.7           | 10          | 14.3           |
|                       | 36–55                             | 143               | 36          | 47.3           | 47            | 62.6           | 60          | 85.7           |
|                       | ≥56                               | 29                | 24          | 31.6           | 5             | 6.7            | 0           | 0              |
| Family size           | ≤2                                | 66                | 36          | 47.4           | 19            | 25.3           | 11          | 15.7           |
|                       | 3                                 | 90                | 24          | 31.6           | 39            | 52.0           | 27          | 38.6           |
|                       | ≥4                                | 65                | 16          | 21.0           | 17            | 22.7           | 32          | 45.7           |
| Education level       | Elementary school and below       | 52                | 38          | 50.0           | 12            | 16.0           | 2           | 2.9            |
|                       | Junior high school                | 88                | 34          | 44.8           | 34            | 45.3           | 20          | 28.5           |
|                       | Senior high school/junior college | 51                | 3           | 3.9            | 21            | 28.0           | 27          | 38.6           |
|                       | University and above              | 30                | 1           | 1.3            | 8             | 10.7           | 21          | 30.0           |

TABLE 3 Results of the questionnaire reliability and validity analyses.

| Dimension                    | Measured variable                  | Validity test                                                                           | Effective factor | Cronbach's $\alpha$ |
|------------------------------|------------------------------------|-----------------------------------------------------------------------------------------|------------------|---------------------|
| Subjective attitude          | X1 Environmental consciousness     | KMO = 0.846<br>Barlett's test Sig = 0.000<br>Cumulative explained variance (%) = 80.577 | 1                | 0.919               |
|                              | X2 Cognitive effect                |                                                                                         |                  |                     |
|                              | X3 Consciousness of responsibility |                                                                                         |                  |                     |
|                              | X4 Personal attitude               |                                                                                         |                  |                     |
| Perceived behavioral control | X5 Family values                   | KMO = 0.729<br>Barlett's test Sig = 0.000<br>Cumulative explained variance (%) = 76.212 | 1                | 0.844               |
|                              | X6 External perception             |                                                                                         |                  |                     |
|                              | X7 Family's ability                |                                                                                         |                  |                     |
| Subjective norms             | X8 Social expectations             | KMO = 0.706<br>Barlett's test Sig = 0.000<br>Cumulative explained variance (%) = 72.841 | 1                | 0.813               |
|                              | X9 Public expectations             |                                                                                         |                  |                     |
|                              | X10 Government expectations        |                                                                                         |                  |                     |
| Behavioral willingness       | Y1 Willingness to participate      | KMO = 0.500<br>Barlett's test Sig = 0.000<br>Cumulative explained variance (%) = 91.477 | 1                | 0.903               |

TABLE 4 Fit of the model on farmers' willingness to comply with the coal-to-electricity policy.

| Fit index             | Specific index | Suggested value                     | Actual fit value |               |             | Result  |
|-----------------------|----------------|-------------------------------------|------------------|---------------|-------------|---------|
|                       |                |                                     | Low-income       | Middle-income | High-income |         |
| Absolute fit index    | CMIN/df        | <3.0                                | 1.015            | 1.688         | 1.194       | Support |
|                       | GFI            | >0.8                                | 0.888            | 0.867         | 0.879       | Support |
|                       | RMSEA          | <0.10                               | 0.016            | 0.096         | 0.053       | Support |
|                       | SRMR           | <0.08                               | 0.058            | 0.071         | 0.065       | Support |
| Relative fit index    | NFI            | >0.8                                | 0.871            | 0.888         | 0.894       | Support |
|                       | TLI            | >0.8                                | 0.997            | 0.931         | 0.973       | Support |
|                       | CFI            | >0.8                                | 0.998            | 0.950         | 0.980       | Support |
| Information criterion | AIC            | Smaller values suggest a better fit | 108.725          | 141.003       | 117.330     | Support |
|                       | CAIC           | Smaller values suggest a better fit | 202.051          | 240.527       | 214.785     | Support |

friends. In areas where low and middle-income farmers account for the majority of the population, these farmers often resist policies that they cannot afford to comply with. They would even feel shunned when their high-income neighbors and friends are supportive of the policies. Based on the path diagram in Figure 4, the path coefficients of public expectations were greatest. When an entire society is advocating for a policy and a high-income farmer's neighbors and friends have all transitioned to using electricity, the farmer's subjective norms would transform into behavior.

#### 4.4 Influence of demographic characteristics on farmers' willingness to comply with the coal-to-electricity policy

This study also investigated the influence of farmers' demographic characteristics (age, gender, family size, and education level) on their willingness to transition to using electricity. According to Table 5, age, family size, and education level had significant effects on the farmers' willingness, whereas the effect

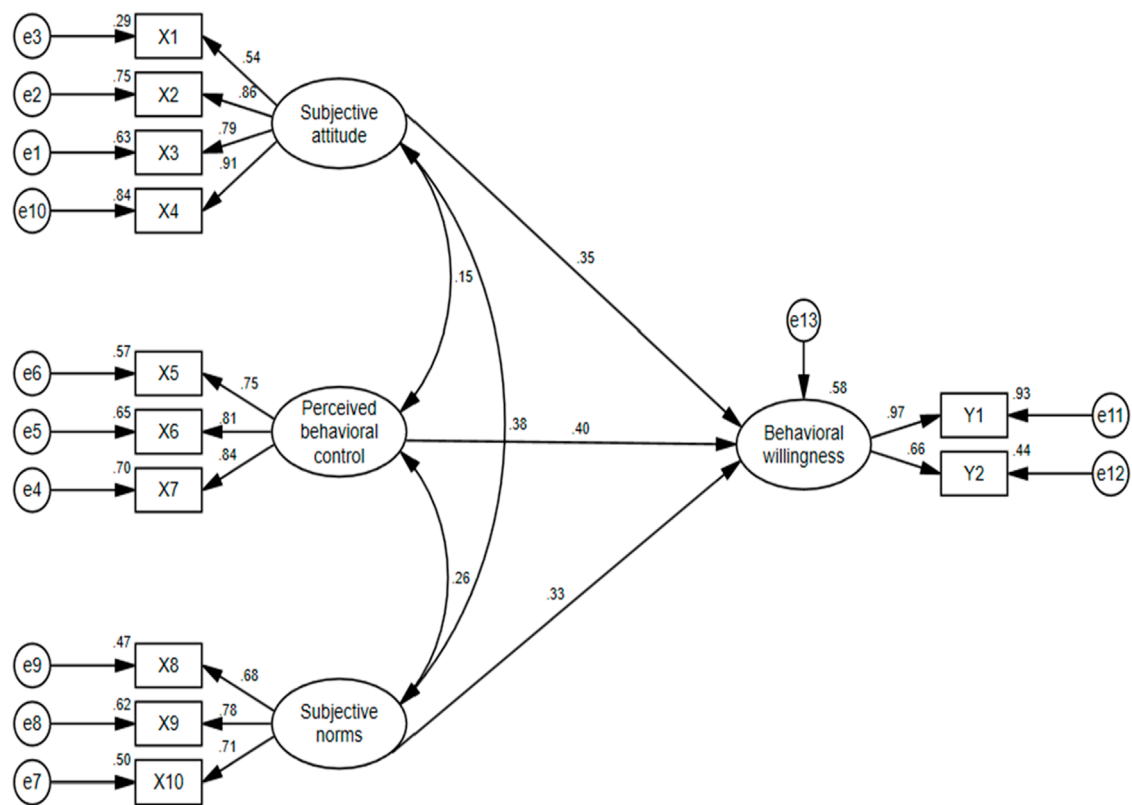


FIGURE 2  
Path diagram of factors affecting the willingness of low-income farmers.

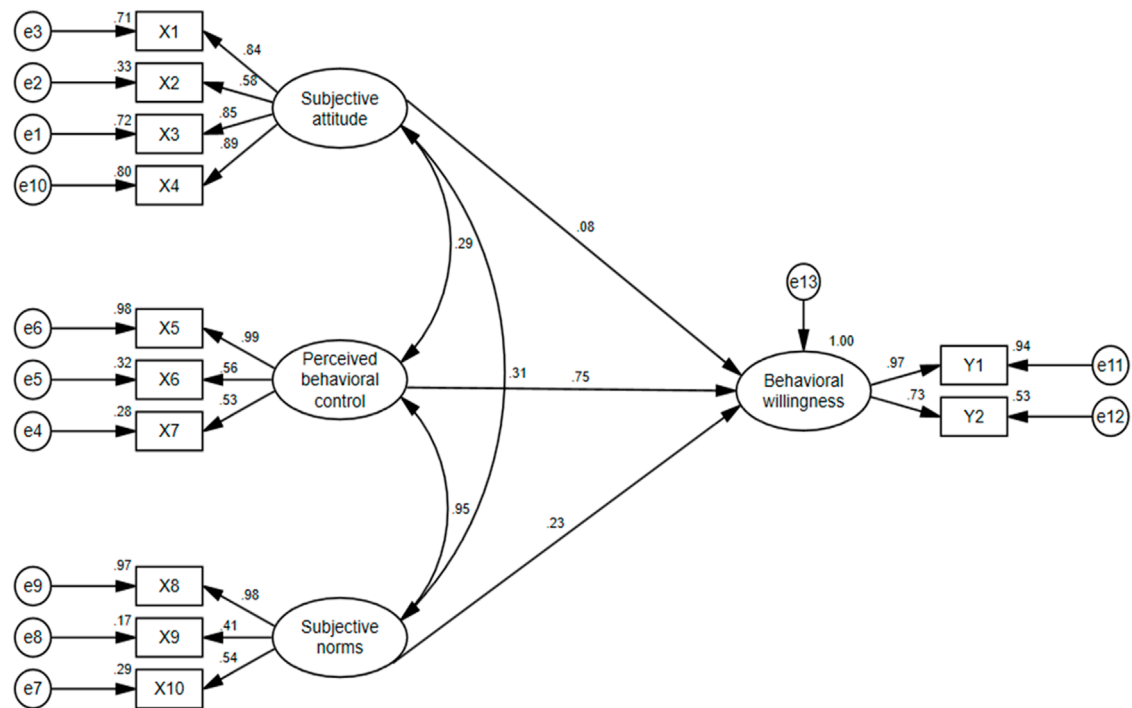


FIGURE 3  
Path diagram of factors affecting the willingness of middle-income farmers.

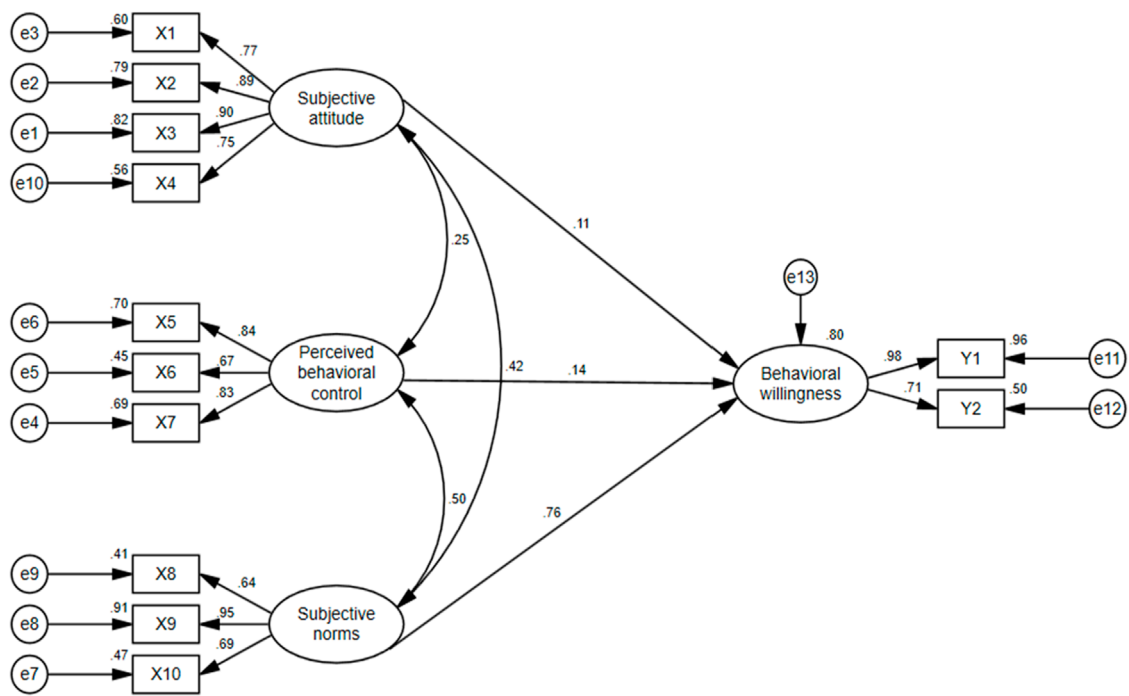


FIGURE 4  
Path diagram of factors affecting the willingness of high-income farmers.

of gender was smaller. Compared to families with four or more members, the likelihood of smaller-sized families having high willingness is lower. The OR value (which indicates high willingness) of farmers aged below 25 years was 3.935 times higher than that of farmers aged above 55 years. This indicates that younger farmers could have a higher willingness. Moreover, compared to farmers who had completed their university education, farmers with lower education levels have lower willingness. Therefore, Hypothesis 4 is validated.

## 5 Discussion

Our findings yield critical insights into the behavioral dynamics of rural energy transitions under China's coal-to-electricity policy, aligning with global efforts to advance equitable and sustainable energy systems. By integrating Ajzen's Theory of Planned Behavior (TPB) with income stratification, this study bridges psychological drivers and socioeconomic heterogeneity, offering novel contributions to energy policy design in developing economies.

### 5.1 Key findings and theoretical implications

This study extends the application of Ajzen's Theory of Planned Behavior (TPB) to policy-driven energy transitions in rural China, emphasizing income heterogeneity as a critical

TABLE 5 Logistic regression result.

| Variable        |                                     | $\beta$   | Exp( $\beta$ ) |
|-----------------|-------------------------------------|-----------|----------------|
| Gender          | Male                                | 0.396     | 1.486          |
|                 | Female                              | 0a        |                |
| Family size     | No. of family members = 1           | -5.109*** | 0.006          |
|                 | No. of family members = 2           | -1.606*** | 0.201          |
|                 | No. of family members = 3           | -0.132    | 0.876          |
|                 | No. of family members = 4 and above | 0a        |                |
| Age             | 25 years and below                  | 1.370**   | 3.935          |
|                 | 25~45 years                         | 0.401     | 1.493          |
|                 | 45~55 years                         | -0.125    | 0.882          |
|                 | 55 years and above                  | 0a        |                |
| Education level | Elementary school and below         | -0.378    | 0.685          |
|                 | Junior high school                  | -1.359*** | 0.257          |
|                 | Senior high school/junior college   | -0.402    | 0.669          |
|                 | University and above                | 0a        |                |

\*indicates a significant level of 0.1; \*\*indicates a significant level of 0.05; \*\*\*indicates a significant level of 0.01.

moderating factor. Our findings reveal distinct decision-making pathways across income groups (Li et al., 2023): Low-income farmers prioritize affordability and perceived control (e.g., subsidy reliance), aligning with prior studies on financial barriers to energy adoption in developing regions (Leach, 1992; Jiang et al., 2004; Zhang et al., 2009). Middle-income farmers exhibit hybrid behavior, balancing policy trust (perceived control) and environmental awareness, reflecting the “fuel stacking” hypothesis (Masera and Navia, 1997; Balances and Countries, 2010). High-income farmers are predominantly influenced by social norms, underscoring the role of group consciousness in rural collectivist societies (Campbell et al., 2004).

This study extends the TPB framework to policy-driven energy transitions, demonstrating how income heterogeneity moderates the psychological pathways influencing compliance. Three distinct decision-making patterns emerged (Li et al., 2023): Low-income farmers prioritized affordability and perceived behavioral control (e.g., reliance on subsidies), underscoring financial barriers as a dominant constraint. This aligns with energy poverty literature highlighting income limitations as a critical hurdle to adopting cleaner energy in rural contexts (Leach, 1992; Jiang et al., 2004; Zhang et al., 2009). Middle-income farmers demonstrate hybrid energy-use behavior, balancing policy trust (perceived behavioral control) and environmental values. Their dual considerations align with the “fuel stacking” hypothesis (Masera and Navia, 1997; Tian et al., 2024a), whereby households maintain traditional fuel use while cautiously adopting modern alternatives, contingent upon economic feasibility and policy credibility. Unlike low-income groups, these farmers possess moderate financial capacity yet remain constrained by budgetary limitations. Consequently, they adopt a fuel-stacking strategy—retaining conventional fuels while gradually integrating renewable energy sources. This hybrid approach reflects both their economic pragmatism and growing environmental awareness (Zhang et al., 2025). In their decision-making process, middle-income farmers prioritize perceived behavioral control factors, such as trust in policies and affordability, over subjective norms (Tian et al., 2025). Nevertheless, they exhibit some responsiveness to collective influence, albeit less pronounced than high-income groups. This complex behavioral pattern indicates that middle-income farmers are in a transitional phase of energy adoption, navigating the tension between economic constraints and ecological values (Tian et al., 2024b; Balances and Countries, 2010). High-income farmers were predominantly driven by social norms ( $\beta = 0.760$ ,  $p < 0.01$ ), emphasizing the role of collective consciousness in rural collectivist societies (Campbell et al., 2004). Their compliance reflects peer influence rather than financial incentives, challenging assumptions that income growth alone drives voluntary transitions.

These results contest the universality of the energy ladder hypothesis in policy contexts, where passive transitions require structural interventions beyond income-driven voluntary shifts (Barnes et al., 1996; Nansaior et al., 2011). By integrating TPB with income stratification, we provide a nuanced framework for analyzing how psychological and economic factors interact to shape energy behaviors.

## 5.2 Policy recommendations

To enhance compliance with China's coal-to-electricity policy, we propose stratified interventions tailored to income-specific barriers (Li et al., 2023): Low-income households: Direct financial subsidies (e.g., upfront installation cost coverage) and skill-building programs (e.g., technical training) are critical to address affordability gaps and perceived control limitations (Zhang et al., 2009). Middle-income households: Middle-income households: Conditional subsidies (e.g., matching funds for energy-efficient appliances) paired with community-led awareness campaigns can leverage their dual focus on economic and environmental values, fostering trust in policy benefits (Balances and Countries, 2010). High-income households: Normative incentives, such as public recognition or social benchmarking, can amplify peer-driven adoption. A comprehensive social benchmarking program include: (i) a tiered “Clean Energy Pioneer” certification system with visible household plaques and digital leaderboards in village centers to create social comparison; (ii) quarterly demonstration events where early adopters showcase benefits and share experiences; (iii) integration with local social credit systems, linking compliance to preferential access to business licenses and agricultural subsidies; and (iv) traditional public recognition ceremonies during village festivals. These normative incentives, grounded in local cultural values and supported by technical assistance (while phasing out direct subsidies), will amplify peer-driven adoption by leveraging this group's demonstrated responsiveness to social norms, while maintaining fiscal efficiency through their capacity for spontaneous compliance.

These strategies align with global evidence on the effectiveness of targeted energy policies (Qi and Li, 2018), while addressing China's unique rural socioeconomic dynamics, advancing progress toward SDG 7 and SDG 13.

## 5.3 Methodological contributions and limitations

This study introduces a replicable analytical framework that integrates TPB with income stratification, offering a blueprint for behaviorally informed energy policy research. However, two limitations warrant attention.

First, Structural equation modeling (SEM) has several key limitations in this study (Li et al., 2023): While the identified associations between psychological factors and behavioral outcomes are statistically significant, the cross-sectional nature of our data precludes definitive causal inferences, highlighting the need for longitudinal research to track the temporal dynamics of policy impacts (Zhang et al., 2009). The model's complexity (with multiple latent variables) risks overfitting, particularly given our moderate sample size ( $n = 221$ ), which may affect generalizability (Balances and Countries, 2010). While SEM accounts for measurement error, unobserved variables could still bias parameter estimates, suggesting findings should be interpreted as probabilistic rather than deterministic relationships.

Second, While our study's focus on Pu County provides important insights into coal-dependent communities (where 28% of villages have historical reliance on coal), the findings may have limited generalizability to regions with differing energy infrastructures and cultural contexts, highlighting three key transferability challenges (Li et al., 2023): the unique economic resistance from entrenched coal-based livelihoods (Zhang et al., 2009), infrastructure-specific switching costs, and (Balances and Countries, 2010) culturally embedded energy norms. To enhance broader policy applicability, we recommend contextual adaptations including: substituting coal-centric messaging with locally relevant narratives such as “firewood-to-electricity” transitions, redesigning incentives to address area-specific barriers, and emphasizing regionally salient co-benefits - all while preserving the core income-stratified approach, though future validation studies across diverse energy ecosystems remain essential to establish the framework's universal robustness.

## 6 Conclusion

### 6.1 Key contributions and findings

This study integrates Ajzen's Theory of Planned Behavior (TPB) with income stratification analysis to examine the behavioral willingness of farmers in passive energy transitions. Through an empirical investigation of 221 rural households under China's coal-to-electricity policy, it reveals income-driven heterogeneity as the core mechanism underlying differences in farmers' behavioral willingness: low-income households, constrained by financial pressures, exhibit heavy reliance on subsidies (Ma et al., 2016; Zhao, 2015); middle-income groups demonstrate a characteristic fuel-stacking pattern that balances policy trust with environmental awareness (Nansaior et al., 2011); while high-income families are predominantly influenced by community norms (Wu et al., 2010). This finding fundamentally challenges the traditional energy ladder hypothesis (Leach, 1992; Jiang et al., 2004), demonstrating that income growth alone cannot automatically achieve energy transition and must be coupled with structured intervention strategies—targeted subsidies for low-income groups, techno-economic composite incentives for middle-income households, and normative guidance for high-income farmers. By extending the TPB framework to policy-driven transition scenarios, this study not only constructs a theoretical framework for how income stratification moderates psychological drivers (attitudes, norms, and control) but also provides an empirical benchmark for designing differentiated and equitable transition policies in developing countries.

### 6.2 Practical relevance for energy policy

The findings offer actionable pathways for designing Sustainable Development Goal (SDG)-aligned policies, particularly SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action). By addressing income-specific barriers, governments can accelerate rural electrification while reducing coal dependency—a critical step for global carbon neutrality efforts.

## 6.3 Future work

Future research should expand this work by incorporating longitudinal data to track behavioral changes over time, examining additional psychological factors like moral norms and environmental identity, and comparing diverse regional contexts across China. Studies could also investigate how local governance structures and implementation quality moderate policy effectiveness, while exploring technology-specific adoption patterns for different clean energy solutions. This expanded approach would provide more comprehensive insights for optimizing targeted intervention strategies in rural energy transitions.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Author contributions

MY: Writing – review and editing, Writing – original draft, Conceptualization. XZ: Writing – review and editing, Methodology, Resources. RG: Writing – review and editing, Data curation. YL: Formal Analysis, Data curation, Writing – review and editing. FZ: Resources, Supervision, Conceptualization, Writing – review and editing.

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## Conflict of interest

Authors MY, XZ, and RG were employed by Information and Communication Company of State Grid Gansu Electric Power Company.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fenrg.2025.1619054/full#supplementary-material>

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