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Determinants of household energy consumption in rural Nueva Ecija, Philippines: A cross-sectional analysis

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ABSTRACT

Economic factors are the most direct and immediate determinants of changes in energy use. Research and development are necessary prerequisites for the demonstration and promotion of energy-related initiatives, while government and private sector efforts are generally essential to initiate and sustain energy conservation activities. The efficient use of energy can be justified on economic, environmental, and social grounds. Therefore, national energy policy should shift its focus from developing new fuels and energy resources to promoting the more efficient use of appropriate energy sources. This study aimed to determine household energy consumption in a rural area, specifically in the municipality of Sta. Rosa, Nueva Ecija. A survey questionnaire was the main research instrument used, supplemented by direct observations of the respondents' habits and practices, as well as interviews. Data on the monthly electricity consumption of each household were also collected. The questionnaire covered six topics: socioeconomic characteristics, fuel and energy sources, household appliances, lighting sources, cooking practices and eating habits, and energy conservation activities. The study found that a coordinated and effective approach to household energy use and conservation can only be achieved through appropriate government involvement to ensure the implementation of the necessary actions and initiatives. The findings may also contribute to the wider dissemination of information and guidelines on energy conservation, particularly if these are incorporated into primary, secondary, and tertiary education or integrated into the school curriculum.

1. Introduction

Household energy consumption is an important development issue in the present study setting because it affects household welfare, energy affordability, and environmental sustainability. In the Philippines, rural households often face high electricity costs, uneven service reliability, and limited access to efficient technologies. These conditions shape how families use electricity for lighting, cooking, cooling, and other daily needs. Understanding the determinants of household energy consumption is therefore necessary for designing policies that promote energy efficiency without reducing quality of life (Lozano and Taboada, 2020). Previous studies have shown that household energy use is influenced by socioeconomic conditions such as income, education, household size, and appliance ownership, as well as by behavioral factors such as energy conservation practices. However, much of the available literature focuses on national or urban-level patterns, while localized empirical evidence from rural Philippine communities remains limited. In particular, there is a need for community-level studies that combine socioeconomic characteristics, appliance ownership, conservation behavior, and verified household electricity consumption data (Nguyen et al., 2025).

This study addresses that gap by examining household energy consumption in the Municipality of Sta. Rosa, Nueva Ecija, Philippines. Specifically, it investigates the relationships between household electricity consumption and selected socioeconomic and behavioral factors, including income, educational attainment, appliance ownership, and conservation practices. The study also assesses how energy use relates to perceived quality of life in a rural setting. The findings of this study provide context-specific evidence that may support local

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energy planning, demand-side management, and energy conservation education in rural communities. More broadly, the study contributes to current discussions on sustainable household energy use in the Philippine context.

2. Literature review

2.1. Theoretical perspectives on household energy consumption

Household energy consumption has commonly been explained using the Energy Ladder Hypothesis, which proposes that as household income increases, families shift from traditional fuels such as firewood and charcoal toward modern energy sources such as liquefied petroleum gas and electricity (van der Kroon et al., 2013). While this framework remains useful, recent studies suggest that many rural households do not follow a strictly linear transition. Instead, they practice energy stacking, in which multiple fuels are used simultaneously depending on cost, availability, reliability, and household preferences (Quirapas Franco and Taeihagh, 2024; Pantuhan et al., 2024). This perspective is particularly relevant in rural communities where households may combine electricity, LPG, and biomass for different end uses.

Another useful framework is the Theory of Planned Behavior, which explains how attitudes, subjective norms, and perceived behavioral control shape individual actions (Ajzen, 2020). In the context of household energy use, this theory helps explain why some households adopt energy-saving practices while others do not, even when they face similar economic conditions. Conservation behaviors such as turning off unused lights, regulating appliance use, and selecting efficient technologies may reduce electricity consumption and are influenced not only by income but also by awareness, habits, and perceived control over consumption choices.

2.2. Empirical studies on socioeconomic determinants

Empirical studies consistently identify income, educational attainment, household size, and appliance ownership as major determinants of residential energy demand. Higher-income households tend to consume more electricity because they are more likely to acquire refrigerators, entertainment devices, fans, and other appliances that increase total demand (Garcia-Miranda et al., 2024). Educational attainment may also influence energy consumption in two ways: it is often associated with higher income and modernized living standards, but it may also improve energy literacy and conservation awareness (Basumatary et al., 2026). Appliance ownership is frequently identified as a direct driver of electricity use because it reflects the actual presence of energy-consuming devices in the home.

2.3. Rural energy use in the Philippine context

In the Philippines, rural household energy use is shaped by affordability constraints, supply conditions, and mixed fuel practices. Studies have shown that electricity costs remain burdensome for many households, while service interruptions and infrastructure limitations affect appliance investment and energy choices (Pepino et al., 2021). Rural households often rely on both electricity and non-electric fuels, particularly for cooking, which reflects the persistence of fuel stacking rather than complete transition to modern energy sources (Quirapas Franco and Taeihagh, 2024; Pantuhan et al., 2024).

Despite these insights, community-specific evidence from rural municipalities remains limited. This study contributes to the literature by examining household energy consumption at the local level in Sta. Rosa, Nueva Ecija, using verified household electricity consumption data and selected socioeconomic and behavioral variables.

3. Methodology

3.1. Research design

This study employed a quantitative descriptive–analytical cross-sectional research design to examine household energy consumption patterns and selected socioeconomic and behavioral factors in a rural municipality of Nueva Ecija, Philippines. The cross-sectional approach was appropriate for describing household characteristics and examining relationships among income, educational attainment, appliance ownership, conservation practices, and electricity consumption measured in kilowatt-hours (kWh) at a specific point in time. The methodological framework aligns with established approaches in household energy demand research (Tran et al., 2023; Duy et al., 2023). By incorporating both socioeconomic and behavioral variables, the design also reflects relevant theoretical perspectives, including the Theory of Planned Behavior (Ajzen, 2020), in examining household energy use.

3.2. Study area

The study was conducted in the Municipality of Sta. Rosa, Nueva Ecija, Philippines, a predominantly agricultural rural locality characterized by mixed residential energy use patterns. Households in the municipality rely primarily on grid-based electricity for lighting and appliance operation, while cooking practices often combine liquefied petroleum gas (LPG) and traditional biomass fuels. The rural context of Sta. Rosa reflects conditions documented in Philippine energy research, including variation in income levels, appliance ownership, and electricity service quality (Pepino et al., 2021). The municipality was purposively selected because it is representative of rural communities in Central

Luzon and was suitable for household-level field data collection.

3.3. Participants and sampling

The household served as the unit of analysis, consistent with conventional methodologies in residential energy consumption research (Sahakian, 2011). Rural barangays officially classified by the Philippine Statistics Authority were identified as the study sites, and households within these barangays were selected using available household listings to obtain a sample appropriate to the objectives of the study. Eligible participants included permanent resident households with active electricity connections and willingness to provide information on monthly energy consumption and socioeconomic characteristics. The sampling approach was intended to capture variation across income levels, educational attainment, household sizes, and appliance ownership profiles, thereby supporting descriptive, correlational, and regression-based analysis (Najeeb et al., 2024; Garcia-Miranda et al., 2024).

However, detailed reporting of the total sample size, number of households approached and completed, number of barangays covered, exact random selection procedure, and formal sample size justification was not fully presented in the original manuscript. This is recognized as a limitation in the methodological reporting of the study and should be addressed more explicitly in future research.

3.4. Data collection instruments

Primary data were collected using a structured survey questionnaire informed by relevant theoretical and empirical literature on household energy consumption (Ajzen, 2020; Tran et al., 2023; Liu et al., 2021). The instrument covered socioeconomic characteristics, fuel and energy sources, appliance ownership and usage patterns, lighting technologies, cooking practices, and energy conservation behaviors. Electricity consumption data were obtained from monthly billing statements or verified electric meter readings, providing an objective basis for estimating household electricity use.

To improve the consistency of responses, survey data were supplemented through structured interviews with household heads and direct observation of appliances and lighting systems where feasible.

3.5. Variables and operationalization

Monthly household electricity consumption, measured in kilowatt-hours (kWh), was treated as the main outcome variable. The explanatory variables included total household income, highest educational attainment among household members, household size, appliance ownership, primary fuel type, and conservation practices. Appliance ownership was operationalized as an index reflecting the number and type of major electrical appliances present in the household. Conservation practices were measured using a composite behavioral index based on reported household energy-saving actions. The index included common practices such as turning off lights when not in use, unplugging appliances or devices when unnecessary, using energy-efficient bulbs, regulating cooking heat, maintaining lighting fixtures and household appliances, defrosting refrigerators regularly, and using available local fuels efficiently when appropriate.

Each reported practice was treated as one component of the index, and responses were consolidated to reflect the extent to which the household engaged in routine conservation behavior. Higher index values indicated greater reported engagement in energy-saving practices. This index was used to capture the behavioral dimension of household energy use, consistent with constructs associated with the Theory of Planned Behavior (Ajzen, 2020) and related empirical studies (Liu et al., 2021).

3.6. Hypotheses

Based on the objectives of the study and the related literature, the following hypotheses were examined:

H1: Household income is significantly associated with monthly household electricity consumption.
H2: Educational attainment is significantly associated with monthly household electricity consumption.
H3: Appliance ownership is significantly associated with monthly household electricity consumption.
H4: Conservation practices are significantly associated with monthly household electricity consumption.
H5: Monthly household electricity consumption is significantly associated with perceived quality of life.

3.7. Data collection procedure

Data collection was conducted through face-to-face household visits by trained enumerators. Prior to fieldwork, the enumerators were oriented on ethical considerations, survey administration procedures, and the process for verifying electricity consumption records. After the purpose of the study had been explained, informed consent was obtained from household heads or authorized adult respondents before the questionnaire was administered. With the respondents' permission, monthly electricity billing statements were reviewed and recorded to improve the accuracy of the reported consumption data. Field data collection was completed within a defined period to maintain temporal consistency in reporting.

3.8. Data analysis

Quantitative data were encoded and analyzed using appropriate statistical software for multivariate analysis. Descriptive statistics were first computed to summarize household energy consumption patterns and socioeconomic characteristics. Pearson correlation analysis was then used to examine bivariate relationships between electricity consumption and key predictors, including income, educational attainment, appliance ownership, conservation practices, and perceived quality of life. Multiple linear regression analysis was subsequently performed to identify statistically significant determinants of household energy consumption and to estimate the magnitude of their effects. Model adequacy was evaluated using the coefficient of determination (R^2), standard errors, and significance levels, consistent with established household energy demand modeling techniques (Tran et al., 2023; Duy et al., 2023).

The statistical procedures employed in this study were limited to descriptive statistics, Pearson correlation, and multiple linear regression, in line with the descriptive–analytical design of the research. However, additional diagnostic procedures such as adjusted R^2, multicollinearity testing using variance inflation factor (VIF), interaction or mediation analysis, and residual normality testing were not included in the original analytical scope. This is recognized as a limitation of the present study. Future research may strengthen the robustness of similar analyses by incorporating these additional statistical procedures.

4. Results and discussion

4.1. Household energy consumption by end use

Descriptive analysis of household electricity utilization in Sta. Rosa, Nueva Ecija revealed that lighting accounts for the largest proportion of total household energy consumption, comprising 73.28% of overall electricity use. Cooking followed at 7.66%, ironing at 6.08%, recreation and entertainment at 4.15%, space cooling at 1.35%, and other miscellaneous uses at 7.48%. The dominance of lighting reflects prolonged daily usage patterns and the limited penetration of highly efficient lighting technologies in rural communities. Although fluorescent lighting is more efficient than incandescent bulbs, full adoption of LED systems remains inconsistent, contributing to sustained electricity demand for illumination. The relatively small share attributed to space cooling is consistent with rural consumption patterns documented in developing contexts, where air-conditioning units are less common due to income constraints and appliance affordability limitations. Cooking energy use, though modest in electricity share, is partially substituted by biomass and LPG, illustrating the persistence of fuel stacking behavior rather than exclusive reliance on electricity (van der Kroon et al., 2013). This finding supports evidence that rural households do not transition linearly along the energy ladder but instead diversify energy sources according to cost and convenience considerations (Quirapas Franco and Taeihagh, 2024; Pantuhan et al., 2024). The concentration of electricity use in lighting suggests significant potential for targeted efficiency interventions. Scaling up LED diffusion, appliance labeling, and consumer awareness programs could substantially reduce rural household demand without compromising living standards, consistent with demand-side management principles outlined in the National Energy Efficiency and Conservation Plan by the Department of Energy (DOE). The findings may also be viewed in relation to broader national household indicators. According to the 2020 Census of Population and Housing, 92.2% of households in the Philippines used electricity for lighting, indicating that electricity already serves as the dominant lighting source at the national level. In addition, the 2023 Family Income and Expenditure Survey reported an average annual family income of PhP 353.23 thousand nationwide. While these national figures are not directly comparable to the household-level results of the present study, they provide useful context for situating the energy use patterns observed in the studied municipality of Sta. Rosa, Nueva Ecija.

4.2. Socioeconomic determinants of household energy consumption

Correlation analysis revealed statistically significant positive relationships between total household electricity consumption and key socioeconomic variables. Household income demonstrated a strong positive correlation with energy consumption ($r = 0.62$), while educational attainment exhibited a moderate positive relationship ($r = 0.48$). Appliance ownership showed the strongest association ($r = 0.71$), indicating that the acquisition of energy-consuming devices mediates the relationship between income and electricity demand. Conversely, conservation practices were negatively correlated with consumption ($r = -0.36$), demonstrating the mitigating effect of behavioral adjustments. These findings align closely with empirical evidence from Philippine household energy demand studies, which show that rising income increases reliance on modern energy services and expands appliance portfolios. As predicted by the Energy Ladder Theory, higher-income households allocate greater resources to electricity and modern fuels, enhancing comfort and convenience (van der Kroon et al., 2013). However, the stronger correlation with appliance ownership than with income alone indicates that material acquisition, rather than income itself, is the proximate driver of increased consumption. Educational attainment also emerged as a significant factor. Higher education levels may expand occupational opportunities and income, thereby indirectly raising energy demand. At the

same time, education enhances awareness of conservation behaviors, introducing a dual effect consistent with behavioral energy models (Ajzen, 2020; Liu et al., 2021). The negative correlation between conservation practices and consumption reinforces the Theory of Planned Behavior, suggesting that attitudes and perceived behavioral control influence actual energy-saving actions.

4.3. Regression analysis and hypothesis testing

Multiple linear regression analysis was conducted to determine the independent effects of socioeconomic and behavioral variables on household energy consumption. The model explained 63% of the variance in monthly electricity consumption (R^2 = 0.63), indicating strong explanatory power suitable for energy demand modeling (Duy et al, 2023; Tran et al., 2023). Household income ($\beta = 0.41$, $p < 0.001$), educational attainment ($\beta = 0.27$, $p = 0.002$), and appliance ownership ($\beta = 0.45$, $p < 0.001$) were significant positive predictors of energy consumption. Conservation practices exerted a statistically significant negative effect ($\beta = -0.19$, $p = 0.014$). The regression results support H1, indicating that household income is a statistically significant positive predictor of monthly electricity consumption. This outcome is consistent with the broader literature demonstrating income elasticity of residential energy demand in Southeast Asia (Najeeb et al., 2024). The results also support H2 and H3, showing that educational attainment and appliance ownership are significant positive predictors of household electricity consumption. In contrast, the negative and statistically significant coefficient for conservation practices supports H4, indicating that behavioral energy-saving actions are associated with lower electricity use. Descriptive and correlational evidence further supports H5, suggesting that household electricity consumption is significantly associated with perceived quality of life. While descriptive evidence indicates that households with higher electricity consumption report improved comfort and convenience, regression findings show that conservation practices can reduce energy use without diminishing perceived living standards. This indicates a non-linear relationship between energy consumption and well-being. Increased energy use beyond essential needs does not proportionally enhance quality of life, echoing findings that energy efficiency—not absolute consumption growth—is central to sustainable welfare improvements. Qualitative observations further suggest that increased energy access may produce mixed social outcomes. Expanded appliance ownership, particularly televisions and digital devices, improves access to information and entertainment but may also alter family interaction patterns. These nuanced outcomes underscore that energy consumption is not inherently synonymous with social progress; rather, efficient and responsible energy use is more strongly associated with sustainable quality-of-life improvements.

4.4. Policy and theoretical implications

The findings reinforce the multidimensional nature of rural household energy consumption. Income-driven appliance acquisition significantly increases electricity demand, yet behavioral interventions can effectively moderate consumption. This dual influence supports integrating structural economic analysis with behavioral frameworks such as the Theory of Planned Behavior (Ajzen, 2020). From a policy standpoint, results align with the objectives of the Philippine Energy Efficiency and Conservation Act (Republic Act No. 11285) and the NEECP 2023–2050, which emphasize demand-side management, local government participation, and educational integration. The prominence of lighting in energy consumption suggests that low-cost efficiency measures, particularly widespread LED adoption, could deliver immediate savings. Moreover, incorporating energy conservation education into primary, secondary, and tertiary curricula may strengthen long-term behavioral change. The persistence of fuel stacking indicates that rural energy strategies must remain context-sensitive. Rather than assuming a linear transition from traditional to modern fuels, policymakers should support diversified, cleaner energy portfolios, including improved biomass cookstoves and decentralized renewable energy systems (Quirapas Franco and Taeihagh, 2024; Gonocruz et al., 2024). The empirical evidence from the studied municipality of Sta. Rosa, Nueva Ecija indicates that household energy consumption is shaped by the interaction of income, appliance ownership, educational attainment, and conservation behavior. Effective policy responses must therefore integrate economic instruments, infrastructure investment, and behavioral education strategies to achieve sustainable and equitable energy use. These policy implications should be interpreted with caution because the findings are based on households in the studied municipality of Sta. Rosa, Nueva Ecija. Accordingly, the recommendations are tentative and should be further validated in other rural settings before broader generalization is made.

5. Conclusions

This study concludes that rural households in Nueva Ecija actively practice basic energy conservation measures, particularly when they are properly informed and oriented. Common practices such as turning off unnecessary lights, maintaining lighting fixtures, using more efficient bulbs, regulating cooking heat, selecting appropriate cookware, defrosting refrigerators, and utilizing locally available fuels reflect practical efforts to reduce energy consumption within existing resource constraints.

However, household energy use increases significantly as educational attainment and income levels rise. Higher education broadens exposure to modern technologies and appliances, while increased income elevates living standards and encourages the acquisition of energy-consuming devices that enhance comfort and convenience. The findings confirm that income, quality of life, and energy consumption are closely interrelated. Moreover, modernization and expanded access to media and appliances may introduce broader social influences, indicating that energy growth is not solely an economic matter but also a social and behavioral concern. Overall, household energy consumption in the rural study area is shaped by both material advancement and value orientation, reinforcing the need for balanced and responsible energy use.

In light of the findings, it is recommended that energy conservation be strengthened through coordinated government action, appropriate energy pricing policies, and sustained public education initiatives. Aligning energy prices with conservation objectives can encourage households to make rational consumption decisions while avoiding unnecessary waste. Government agencies and local authorities should ensure that conservation programs are consistently implemented and monitored to achieve measurable outcomes. Furthermore, integrating energy conservation concepts into primary, secondary, and tertiary education curricula can promote early awareness and cultivate responsible energy behavior among future generations. A cohesive approach that combines policy alignment, institutional support, and educational integration is essential to reduce household energy consumption without compromising the quality of life in rural communities.

5.1. Limitations

The conclusions of this study are based on data collected from a single rural municipality and are limited to the conditions and characteristics of the households surveyed. The reliance on self-reported conservation practices and behavioral observations may introduce response bias, and the cross-sectional design does not capture changes in energy use over time. Additionally, the study focused primarily on household-level factors and did not extensively examine broader structural influences such as regional infrastructure disparities, long-term price fluctuations, or technological access constraints. These limitations suggest that while the findings are meaningful within the study context, broader generalization requires further investigation across multiple rural settings and over extended periods.

List of abbreviations

DOE	Department of Energy
H	Hypothesis
kWh	Kilowatt-hour
LED	Light-emitting diode
LPG	Liquefied petroleum gas
NEECP	National energy efficiency and conservation plan
p	Probability value (p-value)
PhP	Philippine peso
r	Pearson correlation coefficient
R^2	Coefficient of determination (R-squared)
VIF	Variance inflation factor
β	Beta coefficient

Compliance with ethical standards

Ethical considerations

Ethical principles were observed throughout the conduct of the study. Participation was voluntary, and respondents were informed of the purpose, scope, and confidentiality of the research prior to data collection. All information obtained was treated confidentially and anonymized during data processing and analysis. The data were stored securely and used solely for academic and research purposes. Respondents were also informed of their right to decline participation or withdraw from the study at any stage without consequence.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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