Determinants of Household Energy Poverty Status in Eastern Indonesia: A Multinomial Logistic Regression Analysis

Tri Lestari [a,1,*], Geffanio Ardasya W. Risqilla [b,2], Fansza A. Garin [c,3], Jihad Lukis Panjawa[d,4], Fitrah Sari Islami[e,5]

[a,b,c,d,e] Universitas Tidar, Indonesia
[1]trilestari@students.untidar.ac.id*; [2]gfan.awr@gmail.com; [3]adilmagarin37@gmail.com; [4]jipanjawa@untidar.ac.id; [5] fitrahsari@untidar.ac.id
* corresponding author

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ABSTRACT

Energy poverty is a complex, multidimensional issue that can hinder sustainable development in many developing nations, including Indonesia. Although the national electrification ratio has improved, gaps in energy access remain, particularly in eastern regions with limited infrastructure. Most prior studies have focused on national trends or developed areas, often relying on single indicators, leaving little detailed analysis for eastern provinces using multidimensional measures and severity levels. This study examines factors influencing household energy poverty in Papua Pegunungan, Papua Tengah, Papua Selatan, and Nusa Tenggara Timur. Data come from the March 2024 Susenas survey, covering 22,989 households. Energy poverty is classified into three levels, and multinomial logistic regression is applied to assess how household characteristics affect the probability of belonging to each level. Findings show that housing size, settlement type (rural/urban), household head's age, and non-food spending significantly affect energy poverty status. In contrast, education, household size, and household head's sex have no significant effect. These results point to the need for policies that expand equitable energy infrastructure, improve housing conditions, and ensure affordable, adequate energy access across eastern Indonesia.

1.Introduction

Energy poverty holds significant importance within the sustainable development agenda, as it is closely linked to social, economic, and environmental dimensions. Within the Sustainable Development Goals (SDGs) framework, it is recognized as an urgent challenge requiring immediate attention (Sharma et al., 2019; Zetara & Hartono, 2024). It refers to situations where individuals or households lack access to modern, safe, and clean energy for cooking, lighting, or face inadequate fuel availability (Ma & Njangang, 2025; Wojewódzka-Wiewiórska et al., 2024). This concern is global, impacting both developed and developing countries (Abbas et al., 2020; Acharya & Sadath, 2019; Simionescu & Cifuentes-Faura, 2024).

In Indonesia, the problem is most acute in regions experiencing persistent development disparities. Key indicators such as electrification rates and the types of cooking fuel used offer a snapshot of households' access to modern energy. Electrification is closely tied to household productivity, while the adoption of modern biomass is critical for reducing deforestation and mitigating environmental degradation (Akpandjar & Kitchens, 2017; Haidar et al., 2025; Krisianto, 2018). Even though increases in electricity usage may aid poverty reduction, their effect appears comparatively limited (Rahim & Isniawati, 2025). The energy ladder model explains that households gradually transition to cleaner, more efficient energy sources as socioeconomic status improves, yet many in underdeveloped regions remain trapped at lower tiers. From the energy vulnerability perspective, such conditions heighten economic, environmental, and health risks, making electrification and modern biomass adoption critical for productivity gains and environmental sustainability (Adamu et al., 2020; Treiber et al., 2015).

Over the last decade, Indonesia has made notable progress in reducing energy poverty. While the percentage of families using firewood as their main cooking fuel decreased from 24.44% to 8.05%, the national electrification ratio increased significantly from 88.30% in 2015 to 99.48% in 2024. However, these improvements are unevenly distributed across the archipelago. Regions in the east, particularly Papua and Nusa Tenggara Timur, continue to experience low electrification rates and heavy dependence on traditional fuels.

Figure 1 illustrates these disparities: provinces such as Central Papua (56.08% electrification) and South Papua (80.61% electrification) record the highest reliance on

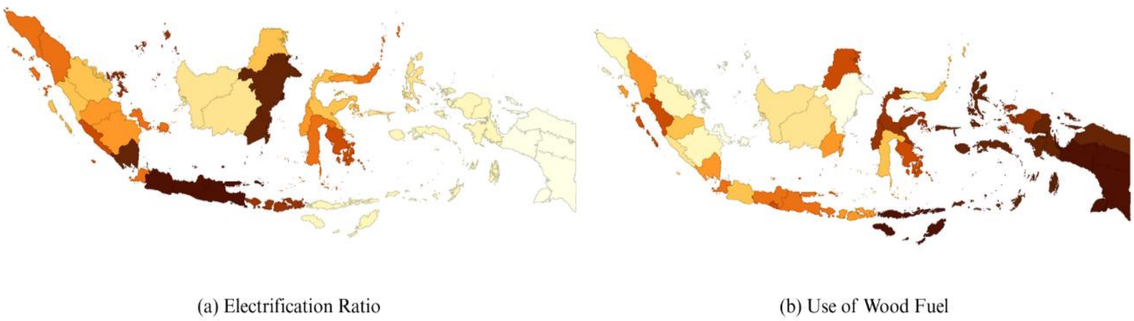

Figure 1 Electrification Ratio and Use of Firewood as the Main Cooking Fuel in Indonesia in 2024 (in percent)
Source: BPS (2024), processed data

firewood ranging from 45.2% to 95.21% while more developed provinces like Jakarta, West Java, and East Kalimantan enjoy near-universal electricity coverage and minimal firewood use. These findings are consistent with prior research (Ashena & Shahpari, 2025), Kuhe & Bisu (2019), and Siksnelyte-Butkiene et al. (2021), which emphasize that access to modern energy strongly shapes household consumption patterns and correlates with socioeconomic and demographic characteristics. This spatial imbalance reveals a fundamental energy inequality problem that mirrors deeper socioeconomic vulnerabilities, including education, gender, age, household size, and geographic location. Studies have consistently shown that higher education levels, female-headed households, and elderly household heads are all associated with varying degrees of energy poverty (Apergis et al., 2022; Crentsil et al., 2019; Ashagidigbi et al., 2020). According to the results of regional poverty studies, there is a significant relationship between lower levels of poverty and educational achievement, as measured by the average number of years of education. This finding supports the idea that better educated households are more likely to have access to and make efficient use of contemporary energy services (Yani et al., 2022).

IEA (2024) data show that while global electricity access has improved, 750 million people mainly in rural Sub-Saharan Africa were still without electricity in 2023. By 2030, this figure is expected to fall only to around 660–663 million. Rural areas remain disproportionately affected, with deficits falling from 886 million in 2010 to 562 million in 2022 but still exceeding urban levels, emphasizing the need for targeted and inclusive energy policies. In Indonesia, electrification is almost universal on an aggregate level, but spatial and socioeconomic disparities remain significant, as shown by a World Bank study by Cornieti & Isabelle (2023). Research by Sambodo & Novandra (2019) indicates that energy poverty varies depending on the indicators used and household characteristics, with determinants that are layered and complex. However, most studies rely on single indicators or affordability measures and focus on national-level analysis without specifically examining disadvantaged regions.

Although national studies have shed light on spatial and socioeconomic disparities in energy access, they often overlook the specific conditions of Indonesia's easternmost regions. In Papua and East Nusa Tenggara (NTT), for example, Hasibuan & Nasrudin (2022) report a relatively high share of energy-poor households. However, comprehensive econometric research in these areas remains scarce, particularly studies that draw on recent data and take into account the creation of new provinces in Papua. Internationally, the index for measuring multidimensional aspects of energy poverty (MEPI) has evolved as a robust tool, yet in Indonesia its application is limited and rarely integrated with probability models that can capture household movements across different energy poverty categories.

Addressing these gaps, this study examines the household characteristics influencing various categories of multidimensional energy poverty in Papua Pegunungan, Central Papua, South Papua, and NTT, utilizing the March 2024 wave of data from the National Socio-Economic Survey (Susenas). By integrating a multidimensional framework with multinomial logistic regression, the study aims to provide region-specific empirical evidence that supports more inclusive and targeted energy policies in under-researched areas.

2. Literature Review

Over the past decade, scholarly interest in energy poverty has increased substantially, driven by its recognition as a multidimensional phenomenon that intersects with social justice, energy transition, and development policy. The academic literature widely acknowledges that energy poverty is not merely a matter of lacking infrastructure but also reflects broader inequalities in income, education, and public service delivery (Husnah et al., 2022). Energy poverty is typically defined as limited access to safe, clean, and affordable energy for basic needs, and is often used as a proxy to measure development disparities within and between countries (Li et al., 2024).

Household transitions in addressing energy poverty are often analyzed through the Energy Ladder Model, which serves as a theoretical guide for understanding the movement from traditional to modern energy sources. The model posits that improvements in income and socioeconomic conditions encourage households to replace solid fuels including firewood, animal dung, and agricultural waste with cleaner and more efficient options such as LPG, electricity, and renewable energy (Heltberg, 2004; van der Kroon et al, 2013). The model associates the lowest stage of energy poverty with reliance on traditional biomass, a fuel source that is inefficient and detrimental to health and the environment. Moving up the ladder requires not only increased purchasing power but also access to infrastructure, knowledge of new technologies, and behavioral change (Masera et al., 2000). Complementing this perspective, the energy vulnerability framework expands the conceptualization of energy poverty by integrating the notion of vulnerability, which encompasses three interrelated dimensions: exposure, sensitivity, and adaptive capacity to energy-related risks (Bouzarovski & Petrova, 2015; Ray & Chakraborty, 2019). Exposure captures the extent to which households are subject to risks such as supply disruptions, price volatility, or natural disasters; sensitivity reflects the degree to which such risks affect households, influenced by variables such as housing quality, household composition, and members' health status; while adaptive capacity refers to the ability of households to adjust to and recover from energy-related shocks, shaped by education, access to information, social capital, and financial resources (Middlemiss & Gillard, 2015).

These theoretical perspectives underscore that inequality in energy access is deeply intertwined with broader socio-economic dimensions, particularly household characteristics. Education emerges as a critical determinant, as higher educational attainment generally reduces the likelihood of energy poverty by enabling access to better income opportunities and, consequently, the affordability of cleaner and more modern energy sources (Drescher & Janzen, 2021; Manasi & Mukhopadhyay, 2024; Maniriho, 2024). Gender dynamics also play a crucial role in determining household vulnerability to energy poverty. Research findings reveal that female-headed households are disproportionately affected compared to male-headed ones, primarily because gender-based inequalities in education, healthcare, and labor market participation limit their ability to fulfill energy requirements effectively (Khairina & Putra, 2023; Ma & Njangang, 2025; Moniruzzaman & Day, 2020; Nuță et al., 2025; Shen, Ma, & Li, 2025). Age is another significant factor in determining household vulnerability to energy poverty. Older heads of households, particularly those aged 60 years and above, tend to have a higher probability of living in conditions with limited access to adequate energy, thereby increasing the likelihood of falling into multidimensional energy poverty (Ogwumike & Ozughalu, 2016; Olaide t al., 2018; Piekut, 2021) .

Other contributing factors to energy poverty include household size. Households with more members generally have greater energy needs, which may drive the use of cleaner and more modern energy, ultimately reducing the incidence of energy poverty (J. J. Chen & Pitt, 2017; Gafa & Egbendewe, 2021). The size of the dwelling is also significantly correlated; larger houses typically indicate a household's capacity to meet its energy needs and are associated with lower levels of energy poverty (Hartono et al., 2020; Saputri et al., 2024; Sharma et al., 2019). Moreover, household expenditure, especially energy-related spending, serves as an important indicator of energy poverty. Higher expenditure levels often signal better access to modern and clean energy, which helps reduce the risk of energy poverty (Gafa & Egbendewe, 2021; Saputri et al., 2024; Sharma et al., 2019). Geographical placement and the level of socio-economic development significantly shape a household's risk of energy poverty. Rural communities, especially in areas with lower population density, are generally more affected than those in urban centers. The primary causes include dependence on traditional biomass fuels like wood, dung, and agricultural by-products, alongside the increased susceptibility of rural areas to policy shifts and economic restructuring processes. (Aristondo & Onaindia, 2018; Dokupilová et al., 2024; Lehtonen et al., 2024) .

Although a large body of literature emphasizes the influence of characteristics such as the age, education, and gender of the household head, along with household size, in explaining energy poverty, other investigations reveal inconsistent or conflicting outcomes. Zahid et al. (2024) found no significant relationship between the educational background of the household head and the likelihood of overcoming energy poverty. Meanwhile, Okyere & Lin (2023) indicated that energy poverty was more prevalent among households with male heads. Riva et al. (2023) showed that larger household sizes tend to increase the use of solid fuels as the primary energy source, which is a strong indicator of energy poverty. Additionally, K. Chen & Feng (2022) pointed out that households living in large but old houses, without basic energy services, or under rental status, are more vulnerable to energy poverty, as these factors increase energy burdens and reduce consumption efficiency. Interestingly, the study by Malik et al. (2024) found that the age of the household head had no significant correlation with energy poverty status, indicating that age may not be a determining factor.

Although numerous studies have examined the determinants of household energy poverty across various regional and international contexts (Abbas et al., 2020; Khanna et al., 2019; Saputri et al., 2024; Zetara & Hartono, 2024), there remains a lack of research that categorizes household energy poverty based on household characteristics at the regional level, especially in the eastern provinces of Indonesia, namely Papua Pegunungan, Papua Selatan, Papua Tengah, and East Nusa Tenggara. Focusing on Eastern Indonesia, this study explores household access challenges to energy in four provinces with notably high energy poverty rates. Its objective is to analyze the role of household characteristics in determining energy poverty classifications in Papua Pegunungan, Papua Selatan, Papua Tengah, and East Nusa Tenggara.

3. Research Method

This research relies on secondary data obtained from the March 2024 wave of the National Socio-Economic Survey (Susenas) carried out by Statistics Indonesia (BPS). The cross-sectional data covers districts and municipalities in Central Papua, Highland Papua, South Papua, and East Nusa Tenggara, with 22,989 household respondents. A quantitative approach is applied using multinomial logistic regression, which is suitable for dependent variables with more than two unordered categories. This method allows simultaneous estimation of the probability of a household falling into each category of energy poverty and facilitates interpretation of how socio-economic and demographic factors influence these probabilities (du Plessis, 2022; Indriany et al., 2019; Nibbering, 2024; Shareef et al., 2024). It is chosen because the dependent variable household energy poverty has three categories: not energy poor, vulnerably energy poor, and severely energy poor, making binary logistic regression insufficient.

The analytical framework for classifying energy poverty is adapted from several prior studies. These include Taye, Assefa, & Simane (2024) on urban household behavior in solid waste management in Addis Ababa, Kalonde et al. (2023) on household waste disposal preferences in Lilongwe, Malawi, Akter & Alam (2024) on individual transport mode choices in university settings, and Čampulová & Čampula (2020) on household car ownership patterns in the Czech Republic. According to IEA (2017), energy poverty describes a condition where households are unable to obtain adequate access to vital energy resources, particularly electric power and contemporary cooking energy sources. Consistent with SDG 7, the core measures comprise electricity availability (indicator 7.1.1) and the adoption of cleaner fuel types, notably liquefied petroleum gas (LPG) for cooking in developing regions (indicator 7.1.2). The classification of energy poverty follows Septiani et al. (2023) dividing households into three categories: less energy poor, more energy poor, and most energy poor. The probability that a given household i is assigned to category j is expressed as $P(y_i = j \mid x)$, which depends on a vector of independent variabels x, such as income, education level, and typr of fuel used. The regression coefficients β_j represent the effect of each independent variable on the likelihood that a household belongs to category j compared to the base category. Since the number of energy poverty categories is three (0, 1, and 2) with category 0 as the reference, the general form of the multinomial logistic regression equation is:

$$P(y_i = 0) = \frac{1}{1+exp^{x'_i\beta_1}+exp^{x'_i\beta_2}} \quad (1)$$

Meanwhile, the equations for categories 1 and 2 are specified respectively as follows.

$$P(y_i = j \mid x) = \frac{exp^{x'_i\beta_j}}{1+\sum_{j=1}^{2} e^{x'_i\beta_j}}, \text{j} = 1,2 \quad (2)$$

The relationship between independent variables and the probability of each energy poverty category is assessed using the following equations. Details of the variables, including definitions and measurements, are listed in Table 1.1. The analytical model is therefore specified as:

$$P(y_i = j|x) = \alpha_i + \beta_{1i}PKRT_i + \beta_{2i}JART_i + \beta_{3i}UKRT_i + \beta_{4i}GJKKRT_i + \beta_{5i}PRT_i + \beta_{6i}UTT_i + \beta_{7i}KW_i + \varepsilon_i \quad (3)$$

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Table 1. Operational Definitions of Variables

Variable	Operational Definition	Proxy	Source
Dependent Variable			
Energy Poverty (KE) Code : R1816 dan R1817	A condition where individuals or households are unable to access or utilize modern energy sources for cooking and lighting.	0 = Household has access to both gas and electricity. "Not energy poor" 1 = Household has access to either gas only or electricity only. "Vulnerably energy poor" 2 = Household has no access to gas and electricity. "Severely energy poor"	SUSENAS
Independent Variables			
Education Level of Household Head (PKRT) Code : R614	The highest level of formal education completed by the household head.	Highest number of years of formal education (0 – 22 years)	SUSENAS
Household Size (JART) Code : R301	How many members of the same home are financially reliant on the head of the household.	Number of household members (persons)	SUSENAS
Age of Household Head (UKRT) Code : R407	The length of time the head of the household has been alive since birth till the survey.	Age of household head (years)	SUSENAS
Gender of Household Head (JKKRT) Code : R405	The gender identity of the household head is categorized as male or female.	0 = Female 1 = Male	SUSENAS
Household Expenditure (PRT) Code : NONFOOD	The total amount of money spent by the household on non-food items within one month.	Monthly non-food household expenditure (IDR)	SUSENAS
Dwelling Size (UTT) Code : R1804	The size of the residence occupied by the household, measured in square meters.	Size of living area (m^2)	SUSENAS
Regional Classification (KW) Code : R105	Classification of areas based on administrative status and demographic characteristics.	0 = Rural 1 = Urban	SUSENAS

Source : Author's calculation based on Badan Pusat Statistik (2024)

4. Results and Discussion

Results

Energy poverty in four provinces located in eastern Indonesia, specifically Central Papua, Highland Papua, South Papua, and East Nusa Tenggara, was examined using data from 22,898 household respondents. Using the categorization framework for energy poverty levels presented in Table 2, approximately 79 percent of households are categorized as experiencing low or vulnerable energy poverty. Around 19 percent are classified under severe energy poverty, and only 2 percent are not considered energy poor. These findings indicate that a significant portion of households in these provinces still face limited access to adequate and and dependable energy resources, which has broader implications for their overall welfare.

Regarding educational attainment, nearly half among household heads have only completed primary school. This is followed by those who completed senior secondary education, comprising 19 percent, and junior secondary education at 12 percent. The proportion of respondents who completed higher education is relatively low, with 5 percent holding a bachelor's degree, 2 percent having a diploma, 0.25 percent a master's degree, and only 0.0001 percent holding a doctoral degree. These statistics reflect a generally low level of formal education, which may influence household consumption patterns, labor productivity, and access to economic opportunities.

Regarding residential distribution, Just 15% of respondents live in cities, compared to 85% who live in rural areas.This pattern suggests that most of the population remains concentrated in rural locations, with availability of vital services and chances for economic participation is generally more limited. Such conditions may exacerbate household vulnerability, especially in terms of energy access. A study in Brebes Regency, Central Java, shows that despite economic growth, uneven development persists, underscoring the need for targeted infrastructure investment an equally critical factor for expanding modern energy access (Febrayanto et al., 2025). From a household structure perspective, the majority of household heads are male, accounting for 84 percent of the sample. Female-headed households make up 16 percent. This indicates a dominant role of men in household leadership, which may reflect persistent gender norms and a socio-economic system that remains patriarchal. The average household consists of approximately four members, with the number of members ranging from one to sixteen. On average, household heads are 48 years of age, with the youngest being 10 and the oldest 97. This implies that a large share of household heads are within the productive age range, which theoretically correlates with higher household economic capacity.

In terms of economic conditions, the average monthly household expenditure on non-food items is recorded at IDR 1,878,281. The range of expenditures varies widely, from IDR 85,916 to IDR 90,271,917. The average floor area of the dwelling is 52.56 square meters, with the smallest dwelling measuring 3 square meters and the largest reaching 500 square meters. These figures highlight a substantial disparity in both consumption and ownership of physical assets, reflecting significant socio-economic inequality among households.

Overall, survey respondents' demographic and economic backgrounds offer a strong foundation for further analysis on household welfare, inequality, and the interrelationships among social, economic, and energy access variables at the micro level.

Variable	Description	Sample Size	
		Total	(%)
Energy Poverty	0 = Not energy poor	493	0,02
	1 = Vulnerably energy poor	17977	0,79
	2 = Severely energy poor	4429	0,19
Education Level of Household Head	0 = Did not complete primary school	3,115	14
	6 = Completed primary school	11,108	49
	9 = Completed junior secondary school	2,841	12
	12 = Completed senior secondary school	4,342	19
	15 = Diploma degree	381	2
	16 = Bachelor's degree	1,051	5
	18 = Master's degree	57	0.25
	22 = Doctorate	3	0.0001

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Regional Classification	0 = Rural area		19,410	85
	1 = Urban area		3,488	15
Gender of Household Head	0 = Female		3,563	16
	1 = Male		19,335	84
		Mean	Min	Max
Household Size	Number of household members	3.82	1	16
Age of Household Head	Age in years	48.11	10	97
Monthly Non-food Expenditure	Household non-food expenditure (IDR)	1,878,281	85,916.67	90,271,917
Dwelling Size	Floor area of residence (m^2)	52.56	3	500

Source: Author's calculation based on Badan Pusat Statistik (2024)

Further analysis related to household welfare, inequality, and the interconnection among social, economic, and energy access indicators in micro-level analysis was conducted using a quantitative approach through the application of multinomial logistic regression. Table 3's estimation findings demonstrate that a number of independent variables have varying effects on a household's probability of falling into a specific energy poverty category. With a Pseudo R^2 value of 0.1134, the model indicates that the independent variables included in the analysis account for around 11.34 percent of the variation in family energy poverty status. Although this value is considered moderate, such results are common in large-scale social surveys. This is because energy poverty is shaped by numerous structural and contextual elements that are not fully captured by individual-level variables in the model. Similar findings are reported by Shah (2020) and Şahin & Kılıç (2021), who argue that despite modest explanatory power, such models still offer meaningful insights into early-stage determinants that are statistically significant and relevant for further in-depth analysis.

Table 2. Multinomial Logistic Regression Results on Household Energy Poverty Status

Multinomial logistic regression						
					Number of obs	22,898
					LR chi2(14)	3066.15
					Prob > chi2	0.0000
Log likelihood	-11984.504				Pseudo R2	0.1134
KE	Coefficient	Std. err.	z	P>lzl	[95% conf.	Interval]
0	(base outcome)					
1						
PKRT	.000026	.0112422	0.00	0.998	-.0220082	.0220603
JART	-.0024625	.0255632	-0.10	0.923	-.0525655	.0476404
UKRT	-.0049916	.0036169	-1.38	0.168	-.0120807	.0020975
JKKRT	-.1030179	.1304404	-0.79	0.430	-.3586764	.1526407
PRT	3.21e-08	2.99e-08	1.08	0.282	-2.64e-08	9.06e-08
UTT	-.0075901	.0005767	-13.16	0.000***	-.0087205	-.0064598
KW	.3926084	.1504884	2.61	0.009***	.0976565	.6875602
Cons_	4.338455	.2760566	15.72	0.000***	3.797394	4.879516
2						
PKRT	-.005507	.0118652	-0.46	0.643	-.0287624	.0177483
JART	.0098657	.026926	0.37	0.714	-.0429082	.0626397
UKRT	-.012533	.00382	-3.28	0.001***	-.0200201	-.005046

JKKRT	-.0325239	.1376727	-0.24	0.813	-.3023575	.2373097
PRT	6.67e-08	3.08e-08	2.17	0.030**	6.38e-09	1.27e-07
UTT	-.0518264	.0012106	-42.81	0.000***	-.0541991	-.0494536
KW	.9540227	.155002	6.15	0.000***	.6502244	1.257821
Cons_	4.900807	.2922644	16.77	0.000***	4.327979	5.473634

Source : Author's own computation in Stata based on data from BPS (2024), Note : Statistical significance levels *** P>|z| < 0.01; ** P>|z| <0.05

The variable of home size was found to have a substantial negative impact on the likelihood of falling into the vulnerable to energy poverty category, according to the analysis in Table 3. This indicates that the larger the dwelling occupied by a household, the lower the chances of encountering inadequate energy access. This illustrates how households with larger living spaces typically enjoy better economic circumstances and have easier access to energy infrastructure, such as reliable electrical networks and well-equipped kitchens. Stated differently, a household's ability to obtain enough energy can be gauged by the size of its home. This conclusion aligns with Hartono et al., (2020), findings which suggest a strong correlation between energy availability and a home's physical condition.

Furthermore, the regional classification variable also shows a notable positive effect on energy poverty. Households living in urban areas tend to be at higher risk of experiencing energy poverty compared to those in rural areas. In urban areas, expenditures for basic needs such as rent, transportation, and food tend to be higher. This condition limits the household budget allocation for energy needs, making urban households inclined toward lower energy usage or opting for unsafe and inefficient energy sources. These outcomes are consistent with those of Cahyani et al. (2022) and Simcock et al. (2021), which indicates that urban households are more susceptible to energy poverty than rural households, especially when household income is taken into consideration.

The age of the household head has a considerable negative impact on homes who are classified as energy-poor. The likelihood of escaping energy poverty is higher for older family heads. The accumulation of life experience, financial security, and better established social networks at later ages can all help to explain this. Due to accumulated assets and knowledge, older family heads are likely to have better access to energy resources, such as power and cooking fuel. Jiang et al. (2024) similarly support this finding, emphasizing the importance of age in enhancing household energy resilience.

Another significant variable is household expenditure, which shows a positive effect on the risk of energy poverty. Although this may appear counterintuitive, higher household expenditure does not necessarily indicate adequate energy access. This may occur if the share of non-food expenditure allocated for energy is relatively small or is instead directed toward other goods and services, such as healthcare. This is consistent with what Boing et al. (2014) found, which notes that poverty may arise when a considerable share of household spending goes toward health and social needs. Similarly, Kassahun et al. (2022) found that non-food household expenditure may contribute to poverty when not accompanied by stable income. In other words, households with high expenditures may still experience energy poverty if there is poor management in allocating spending to prioritize basic needs, such as energy beyond food. Furthermore, the variables of housing size and regional classification again show significance in the energy-poor household category. This reinforces the evidence that physical and spatial factors are important determinants in explaining energy poverty status.

On the other hand, a number of factors, such as the family head's gender, size, and educational attainment, did not significantly affect either type of energy poverty. The lack of significance of education is supported by the findings of Doğanalp et al. (2021), who emphasize that education alone is not sufficient without the availability of adequate employment opportunities. Without decent job opportunities that match both the quantity and qualifications of education, income, and energy access do not necessarily improve. The household size variable also showed no significant relationship with energy poverty, consistent with Septiani et al. (2023), who suggest that family size is not a primary determinant of energy poverty. This is particularly relevant in disadvantaged regions where energy poverty is more influenced by infrastructure and economic factors than by demographic aspects. Furthermore, there is no discernible impact from the gender of the head of the household. This insignificance may be attributed to the limited variation in demographic characteristics within the sample, especially due to the dominance of male respondents. However, if the data distribution were more balanced, it could align with the findings of Okyere & Lin (2023), It implies that men might be more susceptible to energy scarcity.

Overall, these results indicate that housing size, regional classification, household head age, and household expenditure are the most reliable and important factors influencing the state of energy poverty. In contrast, there is no discernible effect of household size, gender, or the head of the household's educational attainment. Thus, structural conditions like energy infrastructure, housing quality, and equitable access to modern energy in terms of quantity and quality as well as affordability should be the main focus of energy poverty alleviation strategies. Long-term policy planning should still take demographics into account.

5.Conclusion

Energy poverty remains a serious challenge in the eastern regions of Indonesia, with many households falling into the categories of low or vulnerable energy poverty. Urban households are more likely than rural households to experience energy poverty, according to the study's intriguing findings. This is largely due to the higher cost of living in cities, including expenses for rent, transportation, and basic needs, which limit the proportion of household expenditure that can be allocated to energy. Additionally, urban households are often more dependent on commercial energy sources, the prices of which are frequently unaffordable for low-income groups. In addition to regional classification, energy poverty status is also greatly influenced by other structural characteristics including household expenditure, household head age, and housing size. On the other hand, demographic factors including household size, gender of the head of the household, and educational attainment do not exhibit any discernible impacts. These findings directly address the research objectives of identifying household characteristics associated with different categories of energy poverty and evaluating their influence on access to clean energy in Papua Pegunungan, Papua Selatan, Papua Tengah, and Nusa Tenggara Timur. By applying a multidimensional classification framework to an under-researched region, the study fills a notable empirical gap in the literature and shows that energy poverty is not solely a rural issue but also a pressing urban concern.

Therefore, policies to address energy poverty should not be exclusively rural-centric, but must also consider the specific conditions of urban areas. These include providing energy assistance for low-income households through temporary subsidies, implementing need-based

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rather than consumption-based tariffs (such as lifeline tariffs), and promoting micro-energy systems in densely populated urban areas. Energy development strategies must also be accompanied by improvements in housing infrastructure, energy use education, and productive economic interventions targeted at energy-poor urban households. This includes ensuring physical energy infrastructure access, improving energy service quality, and addressing the role of social norms in energy consumption behavior. Moreover, this study identifies several limitations, such as the absence of contextual variables related to electricity grid access and clean fuel availability, the lack of consideration for actual energy prices paid by households, and the omission of spatial analysis that could provide deeper insights. Therefore, future research is encouraged to adopt longitudinal and spatial approaches while integrating social and cultural norms to design more effective and responsive energy poverty alleviation policies.

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