Economics Development Analysis Journal Vol. 12 (4) (2023)

Economics Development Analysis Journal

http://journal.unnes.ac.id/sju/index.php/edaj

Household Energy Poverty: Evidence From a Large-Scale Longitudinal Survey

Yustirania Septiani[1], [2]Rr Retno Sugiharti✉, [3]Jihad Lukis Panjawa, [4]Isna Hana Nur Izati
[1,2,3,4]Universitas Tidar

Article Information

History of Article
Received July 2023
Accepted September 2023
Pusblished November 2023

Keywords:
Energy poverty, household demography, household expenditure

Abstract

Energy is a basic household necessity closely related to human health and well-being; unfortunately, not all households have equal access to energy. This condition is referred to as energy poverty, wherein a household lacks access to or cannot afford basic energy services to meet its daily needs. The goal of this research is to analyze the determining factors of the probability of households experiencing energy poverty in Indonesia, focusing on Household Demography and Household Expenditure factors. Using household survey data from IFLS4 (2007) and IFLS5 (2014) and employing Multinomial Logit analysis, this study aims to capture the differences between groups of energy-consuming households. The research findings indicate that households found it easier to access energy (especially gas) after the implementation of the energy conversion policy from kerosene to gas, which began in 2007. Based on the estimation results, the probability of households experiencing energy poverty in Indonesia in 2007 is determined by Education, Income, Spouse Work, Communication Cost, and Health Cost, while in 2014, it is influenced by Education, Spouse Work, Electric Cost, Fuel Cost, Health Cost, and Non-food Consumption. Other indicators of Household Demography and Household Expenditure show different results for each category and period. To address energy poverty, a change in perspective and reform of programs in the energy sector are required. The government can also provide energy subsidies and compensation to poor and vulnerable populations.

✉ Corresponding author :
Address: Universitas Tidar
E-mail: retno.sugiharti@untidar.ac.id

ISSN 2252-6560

INTRODUCTION

The Sustainable Development Goals (SDGs) represent a more comprehensive refinement of the Millennium Development Goals (MDGs). SDGs are development objectives that ensure the sustained improvement of the community's economic well-being, maintain the sustainability of social life, preserve environmental quality, and ensure justice and effective governance that can uphold the enhancement of living standards from one generation to the next. Achieving the SDGs is a global commitment to efforts aimed at the well-being of societies, with one of its goals being affordable and clean energy.

In meeting the standards of a decent life and basic human needs, the role of clean and affordable energy is crucial. Within the SDGs, this aspect is encapsulated in Goal 7, which emphasizes the role of energy in achieving sustainable development. Unfortunately, as of 2020, approximately 760 million people globally still lack access to electricity, and 2.6 billion people continue to rely on high-pollution fuels, especially for cooking (ESMAP Annual Report, 2020).

It is important to note that energy plays a crucial role in providing services such as cooking, refrigeration, and lighting, as well as efficient and reliable transportation and telecommunication services (Jargalsaikhan et al., 2019; Sorrell, Gatersleben, & Druckman, 2020). Furthermore, the lack of access to modern energy services can ensnare groups, communities, and nations in a cycle of poverty, social instability, and underdevelopment (International Energy Agency, 2004). To break this cycle, associations of nations worldwide have collectively agreed to incorporate access to clean and affordable energy as one of the Sustainable Development Goals (SDGs). In this context, Nye (1999) and Reynolds (1984) assert that the relationship between energy use and well-being has been increasingly mobilized in development discourse since the early 20th century with the expansion of the electrical grid.

Indonesia, as one of the countries that has committed to the implementation of the Sustainable Development Goals (SDGs), is dedicated to the successful execution of SDGs programs, including the provision of clean and affordable energy through various activities and strategic measures. Indonesia's commitment is illustrated in Figure 1. Figure 1 demonstrates a significant increase in the electrification ratio in Indonesia. With a target of 100 %, the electrification achievement has improved from 72.95 % in 2011 to 99.20 % in 2020. To reach the 100 % target, the government has undertaken efforts such as developing electrical infrastructure, including solar power plants, in the 3T regions (disadvantaged, frontier, and outermost) using the Special Allocation Fund (DAK).

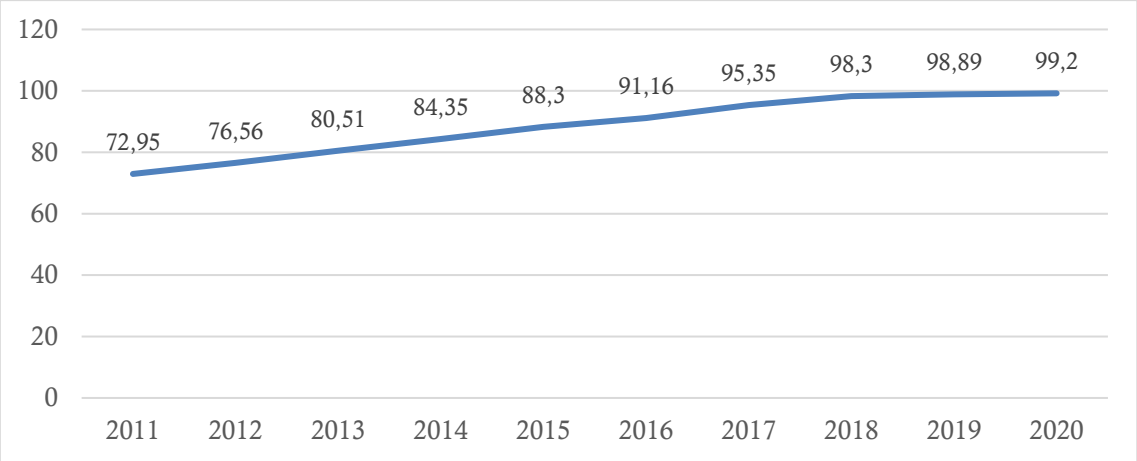

Figure 1. Indonesia's Electrification Ratio in 2011-2020
Source: Central Bureau Statistics, 2022 (Processed)

Nevertheless, behind these policies, there are still issues related to the quality, sustainability, and utility of energy access aimed at supporting productive economic activities. The achievement of a 100 % electrification ratio may seem like a misleading figure because it does not provide a solution to the actual problems, especially concerning the provision of electrical energy and clean energy for cooking. Efforts to address these issues have been undertaken by the government. Since 2017, the government has distributed Solar Energy-Saving Lamps (Lampu Tenaga Surya Hemat Energi - LTSHE) to rural communities without access to electricity. The LTSHE package includes a 20-watt solar power system, four energy-efficient lamps, a battery, installation costs, and after-sales services for three years. Currently, LTSHE users have reached 360,429 households. Unfortunately, LTSHE has not yet met the standards expected by the World Energy Agency, as it only provides lighting and charges mobile phones, not capable of powering other electronic devices such as radios, televisions, fans, and refrigerators. In other words, it has not met global standards (Sambodo & Novandra, 2019).

In addition to energy quality, the issue of inequality in electricity usage also persists in Indonesia. Disparities in the use of electrical energy, particularly the balance between insufficiency and efficiency in energy utilization (Cahyani, Nachrowi, Hartono, & Widyawati, 2022), indicate that a substantial number of Indonesian households continue to face energy insufficiency.

Various previous studies state that a household's inability to achieve a certain level of energy services indicates issues related to energy poverty, also known as fuel poverty (Bouzarovski & Petrova, 2015; Li, Lloyd, Liang, & Wei, 2014). Household energy poverty, also known as domestic energy poverty, is a situation where a household lacks access to or cannot afford basic energy services to meet their daily needs (Che, Zhu, & Wang, 2021). This can include heating, cooling, lighting, and cooking. Energy poverty is a global issue, affecting both developing and developed countries, and has significant social, economic, and environmental impacts. In the literature, the concept of energy poverty has numerous definitions, and its measurement can be accomplished through the use of various indicators (Antepara, Papada, Gouveia, Katsoulakos, & Kaliampakos, 2020; Papada & Kaliampakos, 2020; Sokołowski, Lewandowski, Kiełczewska, & Bouzarovski, 2020). In general, energy poverty refers to a situation where there are challenges in maintaining appropriate (comfortable) temperatures in the residence (heating in winter and cooling in summer) and other issues related to lighting, cooking, and appliance use (Thomson, Simcock, Bouzarovski, & Petrova, 2019).

The inability to achieve basic standards of energy services in households can be attributed to financial situations or the purchasing power of the household (energy/gas prices exceeding the household's payment capacity) and technical conditions (inefficiencies in building and equipment energy). Therefore, the phenomenon of energy poverty can be characterized by the interdependence and interpenetration of socio-demographic, technical, and economic factors with macroeconomic factors (Primc, Slabe-Erker, & Majcen, 2019). According to Che et al. (2021), the availability and affordability of energy are the main obstacles to reducing energy poverty. Meanwhile, in the case of energy poverty occurring in poor households, Sambodo & Novandra, (2019) refer to this condition as double energy poverty or a situation of poverty occurring on two fronts. In this context, double energy poverty is a condition where many people do not have proper access to energy due to low educational levels, weak economic conditions, and the remote locations of their residences, resulting in many households struggling to access electrical energy.

The causes of household energy poverty are multifaceted and vary from region to region. Although Middlemiss et al. (2019) state that social aspects also influence energy poverty, the primary factor contributing to the lack of energy access is influenced by the lack of infrastructure, making the distribution of energy for cooking difficult and expensive, or it can also be due to

changing climate patterns, forcing households to adapt (Thomson et al., 2019). In Indonesia, specifically, several facts contribute to the worsening of this condition. Firstly, almost 30 % of villages throughout Indonesia, or more than 25,000 villages, still use firewood (Podes, 2018). Bahkan hingga saat ini, desa-desa tersebut Even until now, these villages do not have access to clean energy, such as electricity, gas, or biogas, making the use of firewood a priority for the community. Secondly, the subsidy burden continues to increase for the expansion of the utilization of 3 kg LPG (Liquid Petroleum Gas). In 2019, the LPG gas subsidy reached IDR58 trillion, nearly equivalent to the health budget of IDR59.7 trillion.

Thirdly, despite the success of the energy conversion program from kerosene to LPG in 2007, providing access to cleaner and more efficient energy sources for low-income households (Andadari, Mulder, & Rietveld, 2014; Thoday, Benjamin, Gan, & Puzzolo, 2018), the LPG gas subsidy often misses the target as it is consumed more by affluent families. The General National Energy Plan (RUEN) designed until 2050 has mentioned new gas connections in urban areas for 4.7 million homes by 2025 and providing 1.7 million biogas reactors for households. This is also done to achieve Indonesia's target of a 29% reduction in carbon emissions by 2030. However, budget constraints for the development of city gas network infrastructure and the minimal demand conditions to meet the economic scale of gas remain challenges that need to be addressed.

Many researchers have studied household energy poverty. Bouzarovski & Petrova, (2015) suggest an energy service and vulnerability approach that allows a more explicit focus on geographic aspects in detecting domestic energy deficiencies, caused by dimensions such as access, flexibility, efficiency, and uneven energy needs across regions. In line with Bouzarovski & Petrova (2015), Roberts, Vera-Toscano, & Phimister, (2015) found that living in rural areas is closely related to expenditure-based energy poverty, where households in rural areas experience higher energy costs than urban households due to differences in network access costs. Because population density in rural areas is lower, network costs are spread across fewer people. Additionally, concerning the cost of the electricity network, households also have to bear the costs of expanding renewable energy sources because most of them are built in rural areas.

Previous research concludes that energy poverty significantly affects households' wellbeing (Foo, Lean, & Salim, 2021) , and an effective solution to address energy poverty is aid programs. Furthermore, at the aggregate level, Aristondo & Onaindia, (2023) and (Bezerra et al., 2022) observed different categories of countries. The findings of these studies indicate that within one country observed based on regions, there are different energy poverty conditions among regions. Moreover, it results in extreme poverty conditions and high inequality among the poor. On the one hand, a region with a low level of energy poverty does not require many energy poverty reduction policies compared to other regions with high energy poverty. Meanwhile, Bhattacharya, Inekwe, & Yan, (2021) show the heterogeneity of energy poverty in each ASEAN country, specifically concerning energy poverty for electricity consumption and access to electricity.

The study of energy poverty conducted by previous research has focused on various aspects. Earlier studies have extensively examined the socioeconomic impact of energy poverty at the household level, but there is limited research analyzing the changing conditions of energy poverty across generations. Additionally, there is a scarcity of research on the probability of household energy poverty within specific household categories. This study aims to address these research gaps by focusing on the probability of household energy poverty across various energy poverty categories and briefly touching upon intergenerational energy poverty. It utilizes a large-scale longitudinal survey from the Indonesian Family Life Survey (IFLS) waves 4 and 5. The use of IFLS4 (2007) and IFLS5 (2014) data allows for an examination of intergenerational energy poverty movements,

given that IFLS provides panel data every 7 years in survey waves.

In summary, this research aims to compile and analyze the probability of households experiencing energy poverty, considering aspects of Household Demography and Household Expenditure. The observation period covers the time before energy conversion (in 2007) and the year 2014, utilizing data from IFLS4 and IFLS5. The use of Household Demography variables is intended to capture the differences in characteristics between households experiencing energy poverty and those that are not (Cahyani et al., 2022; Lekobane & Seleka, 2017; Nguyen & Nguyen, 2019; Sen, 1995). Meanwhile, the use of Household Expenditure variables serves as a standard proxy for economic factors, providing insights into the household poverty conditions (Kapsalyamova, Mishra, Kerimray, Karymshakov, & Azhgaliyeva, 2021).

Based on the theoretical foundations and previous research outlined, the research model to be tested in this study employs multinomial logit regression. This regression model is characterized by a dependent variable with more than two categories, while the independent variables can be either categorical or numeric. The functional form in this study, derived from the theory and previous research, is as follows:

$$EP = f(\sum Demo, \sum Expend) \quad \text{.....(1)}$$

Where EP as the dependent variable represents Energy Poverty, Demo is a group of variables for Household Demography, and Expend is the socio-economic condition of households measured by household expenditures. The use of Household Demography (Demo) as an exogenous factor of Energy Poverty (EP) has been previously employed by Ogwumike & Ozughalu (2016), Hastuti, Dewi, Pramana, & Sadaly (2020), Awan, Bilgili, & Rahut, (2022) and Famewo & Uwala (2022). Meanwhile, the Household Expenditure (Expend) variable emerges as an independent variable in the study by Sharma, Han, & Sharma (2019).

RESEARCH METHODS

To address the research questions, this study employs a quantitative approach using data from a large-scale longitudinal survey obtained from the Indonesian Family Life Survey (IFLS), comprising two waves: IFLS4 (2007) and IFLS5 (2014). The selection of the 2007 observation period serves as the baseline before the implementation of the Indonesian government's policies outlined in Law No. 30 of 2007 concerning Energy. This law encompasses policies aimed at enhancing energy efficiency, promoting the use of renewable energy, and regulating the sustainable provision and utilization of energy through energy conversion programs. The utilization of the 2014 period aims to capture phenomena occurring after the implementation of these energy conversion policies.

The commonly used method for estimating the relationship between independent and dependent variables is the Ordinary Least Squares (OLS) method. However, OLS is considered highly susceptible to outliers as it relies solely on the mean, making it very sensitive to the presence of outliers, especially in regressions vulnerable to heteroskedasticity in large sample data. Moreover, this method tends to be more suitable for quantitative data.

In addition to OLS, various methodologies such as the Generalized Linear Model, Probit, Logit, and Tobit can be applied when dealing with qualitative variables. Long & Freese (2006) argue that in the case of categorical dependent variables with different and non-substitutable alternatives, the Multinomial Logistic regression works more effectively. Multinomial Logistic regression can be employed in cases where there are more than two possible outcomes for the dependent variable with frequently dichotomous independent variables.

The focus of this research is to analyze the determinants of the probability of household energy poverty, which is divided into four categories based on the clustering of household energy poverty conditions adopted from Gupta,

Gupta, & Sarangi (2020); this categorization is deemed most suitable for conditions in Indonesia.

The four categories for the dependent variable are "least energy poor," "less energy poor," "more energy poor," and "most energy poor." In this type of regression, independent variables can appear in continuous, binary, and categorical forms, or a combination of these. The primary advantage of using Multinomial Logistic regression is its ease of interpretation, but it is somewhat complex due to treating a large number of parameters simultaneously (Cheng & Long, 2007). In general, the equation used is as follows:

$$P(y_i = j|x) = \frac{exp^{(x_i'\beta_j)}}{1+\sum_{j=1}^{3} exp^{(x_i'\beta_j)}} \quad \text{.....(2)}$$

Where i = household 1, … n, and j = household energy poverty category 0,1,2,3 with the baseline category 0. The equation above $P(y_i=j|x)$ represents the probability of the dependent variable, household energy poverty, with the first category being "less energy poor" where j = 0 if the household group can access both gas and electricity (category 0 is the baseline category). The second category is "least energy poor" where j=1 if energy poverty entails having no access to gas but having access to electricity for the household. The third category is "more energy poor" where j=2, representing the condition of energy poverty where the household has access to gas but not to electricity. The fourth category, "most energy poor," where j=3, signifies the condition of energy poverty where the household lacks access to both gas and electricity; this condition is termed energy deprivation (energy used in the household other than gas and electricity, such as firewood or charcoal). All categories apply to each observation I, where xi is the vector of independent variables (household characteristics and conditions) for household i, and βj refers to the vector of estimated coefficients for category j relative to the baseline category.

Detailed explanation of the variables used is provided in Table 1. The interpretation of the model coefficients does not carry a direct economic interpretation but only indicates the direction of the coefficient. Therefore, the marginal probability effect must be calculated to interpret the elasticity effect on the coefficients (Greene, 2003). The research model in this study is as follows:

$$\begin{aligned} P(y_i = j|x) = {} & \alpha_\tau + \beta_{1\tau i} gender_i + \beta_{2\tau i} age_i + \\ & \beta_{3\tau i} educ_i + \beta_{4\tau i} income_i + \\ & \beta_{5\tau i} famsize_i + \beta_{6\tau i} spousework_i + \\ & \beta_{7\tau i} eleccost_i + \beta_{8\tau i} fuelcost_i + \\ & \beta_{9\tau i} commcost_i + \beta_{10\tau i} healthcost_i + \\ & \beta_{11\tau i} nonfoodcons_i + \beta_{12\tau i} foodcons_i \quad (3) \end{aligned}$$

This study utilizes a dependent variable with four categories (j), assuming j–1 logit parameters. This assumption considers the category of households that can access gas and electricity as the baseline, categorical, or reference outcome. The selection of the reference category is done non-specifically, allowing for the choice of any category from j = 0, 1, 2, 3. Therefore, the equation for the reference category, where j=0, can be written as:

$$P(Y = 1) = \frac{1}{1+\sum_{k=1}^{3} e^{(\beta_k' X_i)}} \quad \text{..... (4)}$$

As for the other categories, the equation can be written as follows:

$$P(y_i = j|x) = \frac{exp^{(x_i'\beta_j)}}{1+\sum_{j=1}^{3} exp^{(x_i'\beta_j)}} \quad \text{..... (5)}$$

In multinomial logit, Wald and Likelihood Ratio (LR) tests follow the Chi-square (χ2) distribution and are employed to satisfy the robustness requirements of the model. For testing partial significance, the Wald test is utilized in this research. This test assumes the null hypothesis that the parameter is equal to zero (Hosmer, Lemeshow, & Sturdivant, 2013). In simpler terms, the failure to reject the null hypothesis indicates that the independent variable does not have a significant impact. The functional form of the Wald test is as follows:

$$W = \frac{(\hat{\beta}-\beta_0)}{Var(\hat{\beta})} \sim \chi^2 \quad \text{..... (6)}$$

Furthermore, to obtain the goodness of fit, the research refers to the Likelihood Ratio (LR) test. This test compares the ratio of the

unrestricted model (MUR) to the restricted model (MR). The functional form of the LR test is as follows (Long & Freese, 2014):

$$LR = 2(loglikelihood(M_{UR}) - loglikelihood(M_R)) \sim \chi^2 \quad \text{..... (7)}$$

Table 1. Operational Variables

	Variable	Indicator	Initial
Energy Poverty	Energy poverty in Indonesia is a condition where individuals cannot enjoy modern energy services for cooking or lighting purposes.	Category 1 (least energy poor): Energy poverty in households without access to gas and electricity. Category 2 (more energy poor): Energy poverty in households with access to gas but without access to electricity. Category 3 (most energy poor): Energy poverty in households without access to both gas and electricity. Category 0 (less energy poor): Households with access to both gas and electricity.	***Energy Poverty (EP)***
Household Demography (*Demo*)	Household characteristics are utilized to analyze the social and economic conditions of communities, including aspects related to poverty. Several household characteristics serve as determinants of energy poverty, including gender, age, education, income, family size, and the occupation of the partner. The energy poverty conditions experienced by households vary significantly from one household to another.	Head of Household Gender, a dummy variable (1=Male, 0=Female) Head of Household Age (years) Head of Household Education (Highest education attained by the head of the household/years of schooling) No formal education/incomplete primary school: 0 Primary school/equivalent: 6 years Junior high school/equivalent: 9 years Senior high school/equivalent: 12 years Diploma: 15 years Bachelor's degree: 16 years Master's degree: 18 years Doctorate (Ph.D.): 22 years	***Gender*** ***Age*** ***Educ***

Variable		Indicator	Initial
		Total Household Income (Indonesian Rupiah)	***income***
		Number of Dependents in the Family (individuals)	***Famsize***
		Partner's Employment, a dummy variable (1 = partner employed, 0 = partner not employed)	***Spousework***
Household expenditure (***Expend***)	The household's conditions can be determinants of the likelihood of falling into energy poverty. Various household conditions are influenced by the cost of accessing energy, healthcare service expenses, communication costs, and expenses on both food and non-food items. The cost of accessing energy is proxied by the total electricity and gas expenses; communication costs are proxied by the total household expenditures on telephone and mobile phone credit purchases; health travel costs serve as a proxy for the accessibility of public infrastructure services; consumption costs are divided into two categories: food and non-food expenses. All costs are calculated in Indonesian Rupiah.	Total Electricity Cost (total expenditure on household electricity in the last 1 month)	***Eleccost***
		Gas Fuel Cost (total household expenditure on gas in the last 1 month)	***Fuelcost***
		Communication costs (telephone account payments and total expenditure on vouchers or top-ups or starter packs in the household during the last 1 month)	***Commcost***
		Health travel costs (estimated costs that must be incurred to reach the location of health services in the form of the nearest hospital in 1 trip)	***Healthcost***
		Non-Food Consumption (total non-food expenditure of the household, in the last 1 month)	***Nonfoodcons***
		Food Consumption (total household food expenditure, in the last 1 month)	***Foodcons***

Source: Processed Data, 2023.

RESULTS AND DISCUSSION

Energy is a fundamental human need closely associated with health and human well-being. The Sustainable Development Goals (SDGs) incorporate energy targets to ensure affordable, reliable, sustainable, and modern energy access for all. However, due to various factors, many households still face energy poverty. The objective of this research is to analyze the determining factors of the probability of household energy poverty in Indonesia based

on Household Demography and Household Expenditure for the observation periods of IFLS4 (2007) comprising 12,335 households and IFLS5 (2014) comprising 14,312 households. The results of the multinomial logit model estimation are presented in Table 2.

Table 2. Multinomial Logit Regression Results

Variables	Group 1		Group 2		Group 3	
	Model_2007	**Model_2014**	**Model_2007**	**Model_2014**	**Model_2007**	**Model_2014**
Gender	-0.291***	-0.492***	0.870	-0.708	-0.187	-0.396*
	(-5.76)	(-13.11)	(0.94)	(-1.69)	(-1.68)	(-2.05)
Age	-0.00464***	0.000513	-0.127	-0.0384**	-0.0111**	-0.00839
	(-3.62)	(0.61)	(-1.75)	(-2.60)	(-2.82)	(-1.00)
Educ	-0.229***	-0.113***	0.157	-0.0336	-0.348***	-0.189***
	(-30.79)	(-18.89)	(0.83)	(-0.63)	(-17.03)	(-5.31)
income	-2.36e-08***	-6.33e-09***	3.50e-08**	-3.69e-09	-4.94e-08***	3.50e-09
	(-12.35)	(-4.96)	(2.72)	(-0.32)	(-3.67)	(0.75)
Famsize	-0.00256	-0.0701***	0.607	0.0238	0.192***	0.107
	(-0.16)	(-5.10)	(1.93)	(0.19)	(4.81)	(1.57)
Spousework	-0.255**	-0.891***	-0.302	-0.221	0.456*	-1.088**
	(-2.71)	(-13.17)	(-0.16)	(-0.36)	(2.18)	(-3.06)
Eleccost	3.94e-09	-3.55e-08*	-0.0000109	-0.00000100*	-0.000246***	-0.000000281
	(0.68)	(-2.41)	(-0.58)	(-2.07)	(-18.68)	(-1.08)
Fuelcost	6.63e-08*	7.63e-08*	0.000000145	0.00000107	-0.00000266	-0.0000113**
	(2.13)	(2.36)	(0.49)	(1.84)	(-1.57)	(-2.59)
Commcost	8.45e-09*	-0.00000234***	-0.0000595*	-0.00000539	-0.0000232***	-0.00000560
	(2.10)	(-7.42)	(-2.10)	(-1.24)	(-6.20)	(-1.90)
Healthcost	0.0000643***	0.0000372***	0.000160***	0.0000395*	0.0000964***	0.0000491***
	(3.75)	(5.33)	(4.05)	(2.05)	(4.22)	(5.00)
Nonfoodcons	-2.66e-09**	-1.09e-08***	-6.83e-08	-2.40e-09	-1.35e-08	-8.60e-08*
	(-3.13)	(-4.49)	(-0.45)	(-0.15)	(-1.72)	(-2.14)
Foodcons	-0.000000275**	-0.000000814***	0.000000345	6.09e-08	-0.000000788	0.000000615
	(-3.07)	(-7.87)	(0.11)	(0.07)	(-1.35)	(1.29)
const	4.703***	2.227***	-5.971	-1.755	4.044***	-0.958
	(27.77)	(18.13)	(-1.50)	(-1.49)	(10.14)	(-1.31)
Obs	12335	14312	12335	14312	12335	14312
Pseudo R-squre	0.2546	0.1119	0.2546	0.1119	0.2546	0.1119
Prob > chi2	0.0000***	0.0000	0.0000***	0.0000	0.0000***	0.0000
LR chi2(36)	4099.98	2066.78	4099.98	2066.78	4099.98	2066.78
Loglikelihood	-6002.86	-8203.61	-6002.86	-8203.61	-6002.86	-8203.61
AIC	12083.7	16485.2	12083.7	16485.2	12083.7	16485.2

Notes: t statistics in parentheses; * p < 0.05, ** p < 0.01, *** p < 0.001; *Group1: energy poverty that does not have access to gas but can access electricity for households (least energy poor); Group2: energy poverty that has access to gas but cannot access electricity for households (more energy poor); Group3: energy poverty that does not have access to gas and electricity for households (most energy poor); For the baseline (Group 0) is the group of households that can access gas and electricity (less energy poor)*

Source: Processed Data, 2023.

In this study, the condition of household energy poverty is divided into four categories, with the hope of accurately identifying the characteristics of energy poverty in households in each category, focusing on the most vulnerable group (Group 3). Furthermore, the results of multinomial logit regression are presented in Table 2.

Based on the results of the LR test, it can be concluded that the model is suitable, as evidenced by the LR Chisquare p-value of 0.0000, which is smaller than all alpha levels. This result holds for all categories and all periods. Furthermore, the variation in the probability of household energy poverty in Indonesia in 2007 can be explained by changes in the dimensions of

the Household Demography and Household Expenditure variables by 25.46 %, and in 2014 by 11.19 %, while the remainder is explained by other factors not included in the model.

From the estimation results in Table 2 based on household demography, it can be concluded that in Group 1, namely the least energy poor group in 2007, starting with the variable of the gender of the head of the household being significantly negative, households with male heads who are older, with higher levels of education and income, and have a working partner, have a lower probability of falling into energy poverty compared to non-energy-poor households. Male heads of households, as the backbone of the family, undoubtedly bear significant responsibilities that require them to provide for the family. Those with higher incomes tend to have more financial resources to meet their energy needs, especially with the involvement of the partner in the workforce. When both partners work, the household has an additional source of income. This can help cover energy costs and other household needs. Furthermore, having dual incomes can provide greater financial flexibility. Additionally, a higher level of education is relevant as it can enhance understanding of the benefits of efficient and sustainable energy management. Individuals with higher education may be more likely to adopt technologies and practices that help reduce their energy consumption. However, it is important to note that in Group 1, energy poverty conditions may increase if the young female head of the household works alone and has low income and education levels.

In 2014, there are differences in the determinants of the probability of entering the energy poverty group for Group 1. One of these factors is the number of family dependents, where the larger the family size (Famsize), the more likely it is to have a lower probability of falling into energy poverty for Group 1, while age is not significant. A larger number of family dependents may lead to a lower probability of falling into energy poverty because there are more financial resources and support available within the household. In many cases, having more working family members can generate additional income. Thus, families with many dependents may have more financial resources that can be allocated to energy needs. This includes utility bill payments, energy equipment repairs, and investments in energy efficiency.

An interesting finding from the household expenditure dimension in Group 1 is that households with higher expenses on gas and health are more likely to fall into energy poverty compared to non-energy-poor households in Indonesia in 2007 and 2014. This is because significant expenses on gas and health can reduce the financial resources available to meet other energy needs. However, when observed from other characteristics of household demography in 2007, households in Group 1 are more likely to fall into energy poverty if they have higher communication costs, as well as lower expenditures on non-food and food items. In 2014, the increased likelihood of households in Group 1 falling into energy poverty is largely determined by lower electricity and communication costs, as well as lower expenditures on non-food and food items. The increased probability of energy-poor households due to lower electricity and communication costs, as they focus on cost reduction in these two areas, may result in delays or reductions in expenditures on other energy needs.

Based on the estimation results, the probability of energy-poor households in Group 2, namely the more energy-poor group in 2007 and 2014, is determined by high health expenses. This is because health expenses can reduce the financial resources available to meet energy needs. In various previous studies, the factor of household size (Famsize) has proven to be a major determinant of household poverty in general (Widhi, 2018). Other factors are more determined by increasing income and low communication costs for the 2007 condition, while for 2014, they are determined by the younger age of the head of the household, as well as low electricity and communication costs. In this group, the factors determining the probability of energy-poor households are

relatively fewer compared to other categories. Group 2 (more energy poor) is a more vulnerable group to experiencing energy poverty because they have access to gas but not electricity. From the estimation results, the conditions of factors that can cause households to fall into the energy poverty group are not much different from the baseline (Group 0), which is the group of households that have access to both gas and electricity (less energy poor).

Meanwhile, in energy-poor households in Group 3, the most energy-poor group, consisting of households that do not have access to both gas and electricity, which is a highly vulnerable group to energy poverty, in Indonesia in 2007, is primarily determined by households with a young head of the family with a low educational background, low income, a large number of family dependents, and a non-working partner. In 2014, compared to non-energy-poor households (less energy poor), the determining factors for energy-poor households in Group 3 are a male head of the family with low education and a non-working partner. An interesting finding is that lower education levels lead households to fall into energy poverty. Lower education levels may indicate a lower understanding of the benefits of efficient and sustainable energy management. Individuals with higher education are more likely to adopt technologies and practices that help reduce their energy consumption. Regarding household expenditure, the likelihood of households falling into energy poverty in Indonesia in 2007 is more determined by low electricity and communication costs, while in 2014, it is more influenced by low gas costs and expenditures on non-food consumption. High health costs worsen the condition of households, leading them into energy poverty. When households face high health costs, they may tend to prioritize health expenditures over energy expenditures. Thus, the remaining funds available for energy needs can be significantly reduced. High health costs may make it difficult for households to invest in more efficient energy solutions or switch to more affordable energy sources. They may be stuck with the use of conventional, more expensive energy sources.

Table 3. Marginal Effect

Year 2007				
Variables	**Group 0**	**Group 1**	**Group 2**	**Group 3**
Educ	0.0290639***	-.0254647***	0.000099	-0.0036982***
income	0.00000000304***	-0.00000000232***	1.63e-11**	-0.000000000733**
Spousework	0.0302687**	-0.0481393***	-0.000053	0.0179235***
Commcost	0.0000000637***	0.000000558***	-1.80E-08	-0.000000604***
Healthcost	-0.00000819***	0.00000715***	0.0000000352*	0.000000999**
Year 2014				
Variables	**Group 0**	**Group 1**	**Group 2**	**Group 3**
Educ	0.0203765***	-0.0195755***	0.000013	-0.0008139***
Spousework	0.1593271***	-0.155432***	0.0002073	-0.0041025**
Eleccost	8.84E-09	-0.00000000479*	-0.00000000254*	-1.50E-09
Fuelcost	2.26E-08	0.0000000395**	0.00000000293*	-0.000000065**
Healthcost	-0.00000672***	6.46e-06***	6.91E-08	0.000000192***
Nonfoodcons	0.00000000219***	-0.00000000173***	4.82E-12	-0.000000000466**

Source: Processed Data, 2023.

The Wald test is employed to estimate whether household demography and household expenditure have a significant influence on energy poverty across all categories, testing whether the coefficients of a household demography and household expenditure variable are simultaneously non-zero across all categories. The Wald test results indicate that education, income, partner employment, communication costs, and health costs significantly affect household energy poverty among categories in Indonesia in 2007. In 2014, household energy poverty across categories is determined by education, partner employment, electricity costs, gas costs, health costs, and expenditures on non-food consumption.

Table 3 presents the marginal effects of household demography and household expenditure on households categorized as energy poor. Based on education, households with higher educational levels significantly have a greater likelihood of being in the non-energy-poor group, approximately 2.9 % in 2007 and 2 % in 2014. Similarly, the probability of energy poverty in households decreases for those in category groups 1 and 3. Specifically, in 2007, there is a 0.000000304 % likelihood of households transitioning to the non-energy-poor group influenced by income. This condition is also supported by the fact that decreasing income significantly impacts the increase in energy-poor households. Furthermore, partner employment has a significant influence on the likelihood of households being in the non-energy-poor group, with a percentage of 3 % in 2007 and 15.93 % in 2014. Working partners contribute to additional income, which has the potential to boost the overall household income. With higher income, households can more easily meet energy needs without facing financial difficulties in fulfilling other necessities. This aligns with the likelihood that energy-poor households will decrease when partners are employed.

Furthermore, based on Table 3, according to household expenditure, communication costs significantly influence the likelihood of households becoming non-energy poor in 2007. However, there is a contradictory result that for Group 1, communication costs will worsen energy poverty, while for Group 3, it will reduce energy poverty. In 2014, energy poverty among households between groups is more determined by electricity and gas costs. Low health costs have a significant impact on the likelihood of households becoming non-energy poor by 0.000819 % in 2007 and 0.000672 %. These results are consistent with the idea that high health costs will further plunge households into energy poverty. In other words, health costs affect the status of energy poverty and well-being. With low health costs, households may have more flexibility in planning their budgets. Additionally, with low health costs, households can allocate more funds to energy needs, potentially adopting energy-saving practices. High health costs can quickly deplete household financial resources, resulting in a decrease in income available for daily energy consumption and acquisition.

Energy poverty is a serious socio-economic challenge not only in countries with relatively low socio-economic development but also in highly and very highly developed countries (according to the Human Development Index). Providing safe and sustainable access to energy for citizens at affordable prices is a policy priority. This issue is becoming increasingly important in public discourse and political programs. Energy poverty directly affects the quality of life and health, and it also has significant impacts on the environment. In addition, more attention is being given to the relationship between energy poverty and harmful effects on mental health (Middlemiss et al., 2019).

The use of 2 waves of IFLS data in this study, namely IFLS4 with survey data collected in 2007 and IFLS5 collected in 2014, aims to capture changes in the energy poverty conditions of households based on the implementation of the energy conversion policy from the use of kerosene to LPG. The release of IFLS4 data in 2007 represents the condition before the establishment of the energy conversion policy, while IFLS5 data in 2014 represents the condition of households approximately 6 years

after the establishment of the energy conversion policy.

The four household groups used in this study can be divided into two categories: Group 1 and Group 0 (baseline) represent wealthy households, while Group 2 and Group 3 represent poor households. However, the household conditions in Group 2 are better than those in Group 3 because Group 2 can access gas energy but lacks access to electricity, whereas Group 3 is a poorer group as it lacks access to both gas and electricity. The probability of Group 2 falling into energy poverty is closer or similar to the baseline (Group 3), as evidenced by significant variables such as income, commcost, and healthcost (for the 2007 period) and age, eleccost, and healthcost (for 2014).

Meanwhile, in wealthy households (Group 1), the probability of all variables is smaller than that of the baseline. This finding aligns with the research conducted by Paudel, Khatri, & Pant, (2018) , who found that wealthy households are more likely to use liquefied petroleum gas and fuel wood compared to poor households.

Research findings indicate that households have become more accessible to energy (especially gas) after the implementation of the energy conversion policy from kerosene to gas, which began in 2007. This finding aligns with the study by Liao, Chen, Tang, & Wu (2019), who found that, in addition to previous knowledge on household income, the cooking fuel transition is crucial. This research is also consistent with the study conducted by Kapsalyamova et al. (2021), which shows that access to LPG will increase if the availability of LPG is more evenly distributed..

From the discussion above, it can be seen that there is a complex interaction between health costs and energy poverty, indicating that high health costs can hinder households from escaping energy poverty. This finding is relevant to the research conducted by A'yun & Umaroh, (2023). Therefore, it is important to note that the issue of energy poverty can become a challenging cycle to break. Households with high health costs may be at a higher risk of falling into energy poverty, which can affect their overall well-being. It can be concluded that better access to affordable healthcare and preventive health efforts can help reduce the financial burden associated with high health costs, thereby preventing energy poverty. In 2014, high non-food consumption expenditures would likely increase the chances of households escaping energy poverty, while low non-food consumption expenditures could lead households into energy poverty.

CONCLUSION

The descriptions provided earlier lead to the conclusion that the determinants of energy poverty vary both among each category of household energy poverty and during the observation periods. This research contributes to identifying the determining factors of energy poverty in households in Indonesia. Therefore, it can be concluded that the interventions provided for each household group should be tailored to the characteristics of each household category.

Several efforts need to be made to address energy poverty, such as education, training, and skill development to raise awareness of energy conservation. Developing social assistance programs involving energy subsidies for low-income households and ensuring a decent minimum wage is crucial. Households with working partners can collectively manage budgets, prioritize needs, and efficiently manage time to support energy savings. Adopting efficient household technologies is essential. Adequate health insurance availability is necessary to protect households at risk of high medical costs. Additionally, building partnerships governments, communities, and the private sector is essential to provide sustainable solutions for overcoming energy poverty.

This research has limitations regarding the use of IFLS data, which has specific constraints in terms of geographical coverage, time, and available variables. From a methodological perspective, there are limitations in interpretation. Therefore, further research is expected to provide updated information on poverty conditions by using more recent and

extended time periods, addressing determinants that were not captured in this study, and employing a more comprehensive methodology.

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