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A Multidimensional Energy Poverty in Indonesia and Its Impact on Health

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ABSTRACT

Developing countries, such as Indonesia, still experience difficulties in terms of accessing electricity and meeting the need for clean energy for cooking. Therefore, it is important to measure energy poverty holistically. This study aimed to find empirical evidence regarding multidimensional energy poverty in Indonesia and its impact on health. Energy poverty and health had become a serious concern in the global world, including in Indonesia. However, empirical studies in proving multidimensional energy poverty and its impact on health are still very limited. This study uses a simultaneous equation model with Two-Stage-Least-Square (2SLS) regression method and measuring multidimensional energy poverty through two aspects, namely accessibility and affordability. Results show that low accessibility to electricity leads to a lower health condition and the higher the ratio of energy consumption to total consumption, the lower a household's health condition. The result from the multidimensional energy poverty measurement also shows positive causality with the households' health condition.

1. INTRODUCTION

Energy has an important role in development. The Sustainable Development Goal 7 (SDG7) emphasizes the importance of access to affordable, reliable, and modern energy for all by 2030, including universal access to electricity and clean energy for cooking. Globally, the electrification rate increased from 83 percent in 2010 to 90 percent in 2018. Meanwhile, access to fuels and technology for clean cooking increased from 56 percent in 2010 to 63 percent in 2018 [1]. Electricity supply is needed for lighting, cooking, and heating the house. It is also a basic prerequisite for improving the quality of life [2]. On the other hand, millions of people around the world still lack access to electricity and clean cooking fuels and technology. Difficulties in accessing or obtaining modern energy or energy services lead to the concept of energy poverty which has an impact on productivity, economic, and human development [3].

Developing countries, such as Indonesia, still experience difficulties in terms of accessing electricity and meeting the need for clean energy for cooking. Indonesia accounts for around 2.1% of total electricity poverty in the world [1]. Data from the World Bank in 2014 shows that per capita electricity consumption in Indonesia is still far behind compared to countries in the Southeast Asia region, which amounted to 812 kWh, while Malaysia has reached 4,652 kWh. The International Energy Agency (IEA) report states that 23 million Indonesians do not have access to electricity and around 14 million people rely on solid fuels, such as firewood and kerosene for cooking. The absence of access to electricity is related to malnutrition in rural communities in Indonesia [2]. The use of candles, torches, kerosene, as well as solid fuels, and coal, either for lighting or cooking has serious health implications. It can be made worse if it is done in a room with poor ventilation. In Europe, various health problems associated with inadequate heating are exacerbated by poor housing conditions [4].

Energy poverty is also a complex phenomenon and serious problem in Indonesia. Indonesia has a diverse source of energy, such as oil, gas, coal, geothermal, and solar energy. Yet, the availability and fulfilment of energy access for all regions in Indonesia is a big challenge considering that it is an archipelago with 17,491 islands. Access to electricity in Indonesia is shown by the national electrification ratio which has reached 99.51%. However, there are still gaps in access to electricity between regions in Indonesia, especially in eastern Indonesia, such as the Province of East Nusa Tenggara (NTT) and its surroundings. In the region, the electrification ratio is still far behind compared to other

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regions. In addition, electricity is still difficult to reach due to its high cost because most of the power plants in the NTT region are still based on fuel oil (PLTD) [2].

Various energy development projects that aim to expand Indonesian people's access to energy have been launched by the government in recent decades, including in rural, remote, and underdeveloped areas. One of the programs launched by the government is to provide pre-electrification. In 2019, the Indonesian government through the Ministry of Energy and Mineral Resources (ESDM) has budgeted 328 billion IDR for the distribution of energy saving solar lamp (Lampu Tenaga Surya Hemat Energi/LTSHE) packages. The project distributed 107,877 units of energy saving solar lamp with the provinces of NTT and Papua as the first priority. The project aimed to fulfil the availability of electricity for people in such remote areas. However, the gap still exists; data from the Ministry of Energy and Mineral Resources (2019) shows that the electrification ratio reached 98.81% consisting of 94.97% of PLN electricity, 3.47% non-PLN, and 0.37% LTSHE.

Besides the gap in access to electricity, the gap in access to clean energy for cooking is also high. Indonesian Central Bureau of Statistics (Badan Pusat Statistik/BPS) data shows that in 2018 there were still 21,710 villages/wards that used firewood and 2,979 villages/sub-districts that used kerosene for cooking spread across all provinces in Indonesia. Since 2007, the Indonesian government has also implemented a kerosene-to-LPG (Liquefied Petroleum Gas) conversion policy and provided a 3 kg LPG subsidy for the poor, aimed to reduce the use of kerosene and solid fuels and increase the use of LPG. The kerosene to LPG conversion program has succeeded in reducing the total household kerosene consumption in Indonesia by more than 80% in four years and significantly reducing the infant mortality rate (Imelda, 2020). In addition, the use of solid fuels for cooking contributes to the decline in indoor air quality. It has a major contribution to reducing premature mortality due to air pollution in China, India, and Bangladesh [5]. Some literature shows that energy poverty may not directly lead to death but has a significant effect on the increased risk of respiratory and mental health-related diseases such as an increased risk of depression (for example, [6], [7]).

Most studies on energy poverty measured its broad impact on community well-being but measurement of the specific impact on health is still very limited. Research on energy poverty in developing countries tends to focus on accessibility to modern energy, especially electricity and gas (*e.g.* [2], [8]). In developing countries, the provision of energy access to clean energy for the poor in rural is considered capable of reducing social inequality and increasing participation in society to generate income [9]. Meanwhile, research in developed countries where most of the access to modern energy, especially where electricity has reached 100%, focuses more on affordability and uses the term fuel poverty. As the definition set by the British Government, a household is considered to experience energy poverty if it spends more than 10% of the total family income to heat their house. The same definition applies to France [10].

The concept of energy accessibility and affordability to identify energy poverty needs to be considered in a wider aspect, especially for developing countries [3]. Several studies have shown the negative impacts of energy poverty on the health of individuals, both on physical and mental health. Energy poverty is associated with worse health consequences and has an impact on the overall welfare and quality of household life [10], [11]. Households that still use traditional materials for cooking, such as firewood, has an increased risk of disease from mosquito bites [2], respiratory and circulatory disorders [12], stress [13], depression [14], and decreased physical health and mental health [7]. Although there is some literature on the health impact of energy poverty, studies measuring health impact using multidimensional energy poverty measures are still very limited, especially studies in developing countries (*e.g.* [7], [15], [16]). Therefore, it is important to measure energy poverty holistically as a multidimensional measurement [3].

This study attempted to investigate the impact of energy poverty with multidimensional measurement on health at a household level in Indonesia. This study uses the endogeneity equation model which utilizes the latest national socio-economic survey data (Susenas) and village potential data. Accurate measurement of energy poverty especially at the micro-level is essential for designing efficient energy-related policies [15]. Therefore, it is important to have reliable data or appropriate indicators in measuring energy poverty. This study was conducted using micro-level socio-economic survey data which allows controlling for various household characteristics so that it is expected to produce a more accurate estimate of the impact of energy poverty on health. In addition, this study also considers other health determinants, such as education level, gender, healthcare facility, and others. This study involved a sample of 295,155 households spread throughout Indonesia, using a simultaneous equation model with the Two-Stage Least-Square (2SLS) regression method.

2. LITERATURE REVIEW

2.1 Health

This study's main outcome variable is health status, using the subjective measure of health reports that are assessed by each individual. Llorca *et al.* [14] considered that health analysis at the individual level is considered to be more effective in capturing various factors that explain the different effects of each individual on experiencing fuel poverty. These self-assessed health reports are considered to represent several combinations of health, both mental and physical [17]. The use of subjective information, namely by using the perceived or self-assessed health status is considered to be able to show the actual state of health according to the circumstances of each individual [17]. However, to avoid heterogeneity and individual perceptual bias in self-assessed health reports, it is necessary to avoid

questions with close-range response options, such as "very good" and "good" or "very bad" and bad " [14]. To avoid bias from self-assessed health reports, this study uses questions about health problems from each family member, with a choice of "yes" or "no" responses. The dependent variable in this study is the health status at the household level (Health). This study used a dummy of health complaints from each family member, where 1 is for individuals who have no health complaints at all and 0 for individuals who have health complaints. The total (sum) health complaint in each household as a proxy for the status of household health. In addition, this study also analyzes several individual characteristics that can affect health, such as the age of household head, gender of household head, educational level of household head, and the presence or absence of physical or non-physical limitations.

2.2 Measuring Energy Poverty

Zhang *et al.* [3] revealed that the assessment of the concept of energy poverty through a multidimensional perspective has a very close relationship to understanding its impact on average health in China. China and other countries in Asia have similar and quite significant characteristics [18]. Thus, multidimensional energy poverty through measuring the dimensions of accessibility and affordability is considered capable of seeing energy poverty more broadly so that it can investigate similar health problems, especially in developing countries in Asia [3]. Therefore, this study uses a multidimensional energy poverty measurement through two dimensions; accessibility and affordability, to broadly capture the concept of energy poverty in Indonesia and to analyze its impact on household health. The measurement based on these two dimensions is similar to the study conducted by Zhang *et al.* [3] with a sample of households in China, but with some adjustments. Zhang *et al.* [3] used one indicator for the accessibility dimension because China has reached 100% in terms of access to electricity. In Indonesia, access to electricity is used as an indicator for this dimension of accessibility since the access to electricity has not reached 100%. So that the measurement of the dimensions of accessibility through two indicators, namely access to electricity and access to modern energy for cooking. A dummy variable for the first indicator set equal to 1 for households whose main source of lighting is not electricity and 0 if otherwise. And for the second indicator, a dummy that equals 1 is for household that use biomass fuel for cooking (kerosene, briquettes, charcoal, firewood, etc.), and 0 for otherwise.

The affordability dimension is measured by the indicator of the ratio of household energy expenditure in a year to total household expenditure in a year. Where households are considered to experience energy deprivation if their energy consumption is more than 10% of total expenditure [1]. A dummy set equal to 1 is for households with an energy expenditure ratio of more than 10% of total household expenditure and 0 if for households with an energy expenditure ratio equal to or less than 10% of total household expenditure. Each dimension shows the energy deprivation score of each household. The deprivation score for each household is between 0 and 1. For accessibility (EP_1) and affordability (EP_2), the energy deprivation score can be represented as $d_i = wI_i$ where d_i is the household energy deprivation score, $I_i = 1$ if the household lacks indicators i and $I_i = 0$ otherwise, w is the predefined weight where the total number of weights in each dimension = 1. The multidimensional energy poverty score is the sum of the total deprivation in each dimension. To measure multidimensional energy poverty (EP_3), this study applied the same weight to the dimensions of accessibility (EP_1) and affordability (EP_2) and obtain a household energy deficiency score by calculating the weighted amount of deprivation from each dimension. Some existing literature shows that simple weighting methods to determine multidimensional energy poverty scores can be successful, such as Sadath and Acharya [19], Churchill and Smyth [4], and Zhang *et al.* [3].

2.3 Energy Poverty and Health

Various studies had proven the negative impact of energy poverty on health. Energy poverty causes various physical health problems, from high blood pressure and heart-related diseases [19] to mental health problems, such as anxiety, stress, and depression [20]. Households experiencing energy poverty have a higher tendency to experience physical pain, health, and mental stress [21]. Sadath and Acharya [19] found that the use of various types of solid fuels in the household has a bad effect on the health of each household member. The lower efficiency of traditional fuels and stoves leads to higher smoke release and a decrease in indoor air quality which can be harmful. The direct impact on health is respiratory infections in children and chronic lung disease in women who do not smoke [22], even early death is the biggest risk factor [23], 2011). Households with large family members are vulnerable to experiencing energy poverty [24]. The inability of households to access modern energy leads to dependence on solid fuels such as firewood and charcoal which has the potential to increase the level of indoor air pollution [25].

Eguino [26] showed that the use of biomass and solid fuels, such as wood, coal, and waste materials for cooking and heating, as well as candles and kerosene lamps for lighting, have a substantial effect on health. The effect mainly manifests as respiratory problems caused by high levels of air pollution and inefficient combustion. The inefficient use of biomass fuel had proven to be very dangerous for health [19] which is further exacerbated by the condition of narrow houses and kitchens in houses with poor ventilation, as well as traditional sanitation facilities. Energy-poor households tend to have unhealthy living conditions [27], humid and inadequate [28]. Young children, women, the elderly, and people with pre-existing health problems who are vulnerable to energy poverty [29] have a higher risk of experiencing more serious health problems due to energy poverty [30] because they spend more time at home [26].

Most studies on the impact of energy poverty on health used one measure of poverty as seen from one indicator only, while studies that use multidimensional energy poverty measures on health have not been widely conducted. Sadath and Acharya [19] used a multidimensional energy poverty index through simple weighting of individual components, but it is in line with the Multidimensional Energy Poverty Index (MEPI) which was first developed by Nussbaumer *et al.* [31] to measure multidimensional energy poverty in India. Sadath and Acharya [19] found that different multidimensional energy poverty index scores have different effects on household health risks in India. The higher the energy poverty index score of the household, followed by an increase in tuberculosis, asthma, hypertension, and heart-related diseases experienced by these households. Churchill and Smyth [4] measured a multidimensional energy poverty index similar to Sadath and Acharya [19] by using longitudinal survey data from 2005 to 2017 to see the impact on health status reported by each household in Australia. The results of his research indicated that a high multidimensional energy poverty index was significantly associated with lower household health levels. Zhang *et al.* [3] conducted a study with a multidimensional energy poverty index through two dimensions of energy poverty, namely accessibility, and affordability, and measured the impact on the health status reported by each household in China. The results showed a statistically significant and strong negative impact of multidimensional energy poverty on the health status in China.

3. DATA AND METHODOLOGY

This study uses several data sources, first microdata from the survey results, namely the 2018 National Economic Survey (Susenas); and second, the Village Potential Data Collection (Podes) in 2018 at the District/City level. This study used microdata from the March 2018 Susenas. March 2018 Susenas was conducted in 34 provinces in Indonesia with a sample of 295,155 households spread across 514 districts/cities in Indonesia. The Susenas data used in this study comes from two questionnaires, namely the Kor Susenas (VSEN18.K) and the Consumption/Expenditure Susenas (VSEN18.KP). This study also uses the 2018 Podes Data Collection. The 2018 Podes data covers 83,931 village-level government administration areas consisting of 75,436 villages, 8,444 sub-districts, and 51 UPT/SPT. Podes 2018 also recorded 7,232 sub-districts and 514 districts/cities. In this study, we use household expenditure data as a proxy of household income to measure energy poverty.

In the Indonesian context, household expenditure data portray income conditions better than income data since the data only includes samples from people working in the formal sector, while most Indonesians work in the informal sector.

The econometric model used in this study is a model to see the effect of energy poverty on health in Indonesia. The equation model to be built is an endogeneity equation model to ensure the causal relationship between energy poverty variable and health [4]. The variable health status (Health) is measured by the total number of household members who were experiencing health complaints in each household. The main challenge in this research is the problem of endogeneity which may be caused by reverse causality between energy poverty and health. Several studies have treated energy poverty as endogenous (*e.g.* Churchill and Smyth [4] in Australia, and Zhang *et al.* [3] in China). The health status of a household can affect its level of income, thus causing energy poverty [3]. To reduce this potential endogeneity problem, this study used instrumental variables (IV) as an alternative to empirical strategy. This study uses different IVs for each dimension (accessibility and affordability) and adopted a simultaneous equations model with the 2SLS regression method. IV for accessibility dimension (EP_1), this study incorporated forest variable as a proxy for geographical condition 4. Geographical conditions are considered as one of the factors that influence energy poverty experienced by households [2], [29]. Energy poverty in rural and remote areas tends to be worse. In Indonesia, addressing energy poverty due to unfair distribution in remote areas is still a challenge [32]. In addition, geographic conditions are considered to have no effects on the health status of individuals or households. Therefore, geographical variables are considered capable of being instrumental variables to overcome the problem of endogeneity in this study. Forest variable information is obtained through the PODES 2018 questionnaire. Meanwhile, for the affordability dimension (EP_2), this study uses the Newroad variable as an instrumental variable. Newroad variable is used as a proxy for infrastructure conditions. Infrastructure is considered as one of the factors that cause energy poverty [33]. Areas with already-constructed road conditions are usually followed by the construction of a national grid. Thus, it can be concluded that areas with better infrastructure will have a national grid connection [2]. Road variable information is obtained through the PODES 2018 questionnaire.

To estimate the effects of energy poverty and household characteristics on health status this study employed the following 2SLS model. The variables in the model are based on the study of Churchill and Smyth [4] which has described the causal relationship between energy poverty and health by taking account of endogeneity.

$$\begin{aligned} Health_h = {} & \gamma 0 + \gamma 1\, EP_i + \gamma 2\, GenderHH \\ & + \gamma 3\, AgeHH + \gamma 4\, Disability \\ & + \gamma 5\, Employment \\ & + \gamma 6\, Education \\ & + \gamma 7\, Number\ of\ MemberHH \\ & + \gamma 8\, House\ Own + \gamma 9\, House\ Size \\ & + \gamma 10\, Healthcare\ Facility \\ & + \gamma 11\, Island + \varepsilon_h \end{aligned} \quad (1)$$

The variables are defined as follows: Health is household's health status; EPi are energy deprivation at

dimensions of accessibility (EP_1) and affordability (EP_2), and multidimensional energy poverty variable (EP_3); GenderHH is dummy variable for gender of the head of the household with female as a basis = 0, male = 1; AgeHH is age of the household head; Disability is total number of families who have any kind of disabilities; Employment is dummy variable status of the head of the household in the household with unemployment as a basis = 0, employment = 1; Education is dummy variable for education level of the head of the household with undergraduate and above as a basis = 0, and below undergraduate = 1; Number_of_Member is total number of family members in the household; House_Own is dummy variable for home ownership with others as a basis = 0, the house is owned by the household itself = 1; House_Size is size of the house that is the residence of the household (m2); Healthcare facility is total number of health facilities available in the area of residence (district/city level); Island is island dummies; h is Household h; $\boldsymbol{\varepsilon}$ is error term. The authors did not add the household income variable as a control variable in Equation 1 since it is one of the components of the measurement of affordability as one of the energy poverty variables. Including household income/expenditure as its proxy in the equation would lead to a multicollinearity problem.

4. RESULTS AND DISCUSSION

Based on Table 1, the group of households that experienced multidimensional energy poverty at the 50% highest score of multidimensional energy poverty score was the households living in rural areas. Households living in rural areas were more likely to experience more severe multidimensional energy poverty compared to those living in urban, namely 71,444 households or 76,87% of the total households compared to the total number of households that have multidimensional energy poverty at the 50% highest score. While households who lived in urban areas, only 21,493 households or 23.13% had been experiencing multidimensional energy poverty at the 50% highest score of multidimensional energy poverty score. This is in line with the research of Sadath and Acharya [19] and Zhang *et al.* [3] which showed that households in rural areas experienced more multidimensional energy poverty compared to households in urban areas. This can be caused by the location of the residence which is far from the main road and the difficulty of access. Demographic, socio-economic conditions clarify the differences in characteristics between households with low health status and households with high health status. The factors that caused health status are interrelated, namely the classification of the area of residence, gender of the head of the household, the marital status of the head of the household, the illiteracy status of the head of the household, the educational history of the head of the household and the work status of the head of the household. The area of residence was divided into two categories, namely rural and urban.

Table 1. Households multidimensional energy distribution according to the area of residence.

Area of Residence	Multidimensional Energy Poor Highest Quantile	Multidimensional Energy Poor Lowest Quantile
Urban	21,493	97,145
	(7.28)	(32.91)
Rural	71,444	105,073
	(24.21)	(35.60)
Total	295,155	

Household multidimensional energy poverty status is also divided into 2 quantiles based on the multidimensional energy poverty score, where the highest quantile shows households with the highest 50% multidimensional energy poverty score of the total score, the lowest quantile shows households with the lowest 50% multidimensional energy poverty score of the total score.
Source: Calculated from Susenas 2018 by Authors.

Based on Table 2, there was a difference in the percentage of household health status living in urban and rural areas. Although it did not have a large enough difference, the percentage of households with poor health status is more experienced by households in rural areas, namely 13.56% compared to households living in urban areas, namely 13.47%, as seen in the health status lowest group. Meanwhile, the percentage of households with better health status was mostly experienced by households in urban areas, namely 39.32% compared to households living in rural areas, namely 39.37%, as seen in the highest health status group. These findings were in line with the results of the study by Zhang *et al.* [3] that households in rural areas are more likely to have a lower health status than households in urban areas because rural areas are more prone to experience energy poverty according to the findings in Table 2. So that more households in rural areas use biomass fuels, such as firewood, kerosene, and charcoal which are harmful to health. In addition, from the total number of health facilities in Indonesia, only 31.2% were available in rural areas, far less than the number of health facilities available in urban areas, which was 68.8%. The gender of the household head shows a different proportion of the health status of the household. In Table 2, the group of households headed by women tends to have a better health status than groups headed by men. Based on the age of the household head, health status also has a different distribution. The age classification was based on the classification applied by the United Nations [34], namely, adolescents and adult adults between the ages of 11-24 years, older adults between the ages of 25-64

years, and the elderly are those aged 65 years and over. Based on Table 2, in the lowest health status group, the largest percentage were households with elderly heads of household, which amounted to 32.72%. Meanwhile, the lowest percentage in the lowest health status group is households with adult heads of household, which was 19.98%.

Table 2. Percentage of health status according to household socio-economic characteristics in Indonesia in 2018.

Household Socio-Economic Characteristics	Quartile of Health				TOTAL
	1	2	3	4	
Residence Area					
Urban	39.32	30.85	16.25	13.47	100
Rural	39.37	29.89	17.23	13.56	100
Gender Head of household					
Female	39.72	40.84	12.27	8.17	100
Male	39.48	28.38	17.64	17.64	100
Age Head of household					
Youth and Young Adults (11-24 years old)	27.11	18.74	2.78	51.37	100
Older Adult (25-64 years old)	19.98	23.30	16.14	40.58	100
Elderly (>65 years ole)	32.72	25.07	9.52	32.69	100
Job Status HH					
Employment	40.72	28.90	16.49	13.89	100
Unemployment	34.28	35.55	18.03	12.14	100
Educational level HH					
Below Senior High School	37.44	31.14	17.76	13.23	100
Higher Education	43.13	28.67	14.97	13.67	100
House Ownership					
Own house	20.46	23.10	15.41	41.04	100
Others	26.26	24.39	13.31	36.04	100

Note: Health status is divided into 4 quantiles, wherein quantile 1 shows the household with the highest 25% health status of the total household, while quantile 4 shows the household with the lowest 25% health status of the total household.
Source: Calculated from Susenas 2018 by Authors.

Based on the employment status of household heads, health status also has a different distribution. From Table 2, at the lowest health status group, the largest proportion in households with a head of household who work, which is 13.89% compared to the head of a household who are not working, which is 12.14%. In the highest health status group, households with heads of household who work also have the highest proportion, namely 40.72%, compared to households with heads of household who are not working, which is 34.28%. The educational level of the household head also showed a different distribution of health status. In the lowest health status group, households with a head of household who had education below undergraduate had the highest proportion, namely 13.23% compared to other levels of educational history. Meanwhile, in the highest health status group, households with highly educated heads of households also had the highest proportion, namely 43.13%, compared to other levels of educational history. This finding was in line with the research results of Churchill and Smyth [4], Kiuila and Mieszkowski [35], Buckley *et al.* [36] who showed that the higher the level of education, the better the health status because they have a better understanding of health issues that affect behavior change in a healthy lifestyle.

4.1 2SLS Regression Method

In the first stage, as shown in Table 3, the instrumental variable forest consistently showed a positive and significant association with energy deprivation both in the dimensions of accessibility (EP_1) and affordability (EP_2), and also multidimensional energy poverty (EP_3). These results indicated that households living in forests are positively associated with all forms of energy poverty. While the instrumental variable road consistently showed a negative and significant association with energy deprivation both in the dimensions of accessibility (EP_1) and affordability (EP_2), and multidimensional energy poverty (EP_3). These results indicate that households living in areas with asphalt roads are negatively associated with all forms of energy poverty.

In the second stage, based on the results of IV 2SLS in Table 4, energy deprivation in the accessibility dimension (column 1) and multidimensional energy poverty (column 3) experienced by households are

negatively related to household health status and significant at the 1% level. This shows that households experiencing any form of energy poverty have a lower health status. This result is in line with the results of the study from Zhang *et al.* [3]. While energy deprivation in the affordability dimension (column 2) experienced by households was positively related to household health status and significant at the 1% level. This finding indicated that with each increase in the energy deprivation score from the affordability dimension of a household, household health status score will decrease. The positive coefficient in column (1) indicates that when households do not have any access to electricity and gas, households tend to have lower health status which is marked by the high number of family members experiencing health complaints. Sovacool [37] stated that many studies in developing countries have shown a strong association between health complaints such as respiratory infections, lung-related diseases, and lung cancer experienced by households that use solid fuels. Column (2) shows that with each increase in the energy deprivation score from the affordability dimension of a household, household health status score will increase. The negative coefficient indicates that when households have to spend more money on energy, households tend to have lower health status. In column (3), it can be seen that for each increase in the multidimensional energy poverty score of a household, household health status score will decrease. The positive coefficient indicates that any form of energy poverty will affect household health status. This effect applies specifically to the household that lives in remote areas, especially those who live in the forest, and with inadequate infrastructure, especially those who live in an area with unpaved roads. Households who live in the forest and an area with unpaved roads with any forms of energy poverty have higher health complaints. This study showed energy deprivation from dimension accessibility and the multidimensional energy poverty dimensions consistently correlated negatively with health status, significant at the 1% level. These results show that all forms of energy poverty are still a challenge in Indonesia. The positive coefficient indicates that any form of energy poverty will decrease household health status, especially those who live in the forest and those who live in an area with unpaved roads. This study found energy deprivation from dimension affordability all dimensions correlates positively with health status, significant at the 1% level. While dimension affordability was insignificant in a study by Zhang *et al.* [3]. This shows that affordability to energy has a different effect between Indonesia and China, although both are developing countries. This could be explained by the findings of Sambodo [2] that households who do not experience energy poverty have a higher intensity of health service use which is indicated by having increased health expenditure. Because energy spending is reduced, it can be split into health spending. So, it could have an impact on improving household health status. In addition, household demographic, socio-economic characteristics, such as having family members with disabilities, lower level of education of the head of the household, having more family members, and house size. Those household demographic and socio-economic characteristics correlate negatively and significantly at the 1% level.

Table 3. First stage estimation results for effect of geographical and infrastructure conditions on energy poverty.

	EP_1	EP_2	EP_3
	(1)	(2)	(3)
Forest	0.0001355***	0.0000227***	0.0000791***
	(0,00000277)	(0,00000289)	(0,00000203)
Newroad	-0.0004874***	-0.0001201***	-0.0003037***
	(0,00000984)	(0.0000103)	(0,00000721)
Control Variables	Yes	Yes	Yes
Provincial Dummies	Yes	Yes	Yes
N	295.155	295.155	295.155
Wald F-Statistics	29.858	29.858	10.705

Note: *, **, ***: Indicates Significance at the 10%, 5% and 1% levels. Standard errors in parentheses.
Source: Calculated from Susenas 2018, Podes 2018, and Bps 2018 by authors

Households with older household heads tend to have a lower health status. In addition, the education level of the head of the household in this study shows that the lower level of education of the head of the household has an association with the lower health status of the household. This finding is in line with the studies from Churchill and Smyth [4], Llorca *et al.* [14], and Lin and Okyere [7] which stated that employment and higher education are associated with better health. Households consisting of a lot of members and more than one family living together in one house tend to have a lower health status. Likewise, households with family members with disabilities tend to have lower health status. Those results are in line with the results of a study from Churchill and Smyth [4] that households with family members with disabilities tend to have lower health status. A household with a greater number of dependants also has a lower health status. This finding is in line with the studies from Churchill and Smyth [4], Zhang *et al.* [3], Llorca *et al.* [14], and Lin and Okyere [7].

Meanwhile, the demographic and socio-economic characteristics of the household that were positively related to health status were male household head, employment status of household head, ownership of a house, and healthcare facility. Households that have a

female head of household have a lower health status than households that have a male head of household. This finding is in line with the studies from Churchill and Smyth [4], Llorca *et al.* [14], and Lin and Okyere [7] which stated that household health status is getting better for households with male heads of families. Households with working heads of households have a higher health status. In addition, the education level of the head of the household in this study shows that the higher the education level of the head of the household, the higher the health status of the household. These two findings were in line with the studies from Churchill and Smyth [4], Llorca *et al.* [14], and Lin and Okyere [7] which stated that employment and higher education are associated with better health. Households with self-owned house ownership also have higher health status. Otherwise, the larger the house size, the lower the household health status. Otherwise, the larger the house size, the lower the household health status. This is because although the size of the house is larger, it is not well ventilated, the effects of air pollution will be worse [38].

Table 4. Estimation results of two-stage-least-squares (2SLS) regression method.

Dependent Variable:Health	I	II	III
Independent Variable:	(1)	(2)	(3)
EP_1	0.515***		
	(0.241)		
EP_2		-4.493***	
		(0.906)	
EP_3			13.032***
			(4.657)
GENDERHH	0.059***	0.059***	0.268***
	(0.022)	(0.022)	(0.080)
AGEHH	0.008***	0.008***	-0.013
	(0.001)	(0.001)	(0.005)
DISABILITY	0.398***	0.398***	0.102
	(0.043)	(0.043)	(0.114)
EMPLOYMENT	-0.067***	-0.067***	-0.104***
	(0.008)	(0.008)	(0.019)
EDUCATION	-0.081***	-0.081***	-0.446***
	(0.014)	(0.014)	(0.187)
NUMBER_OF_MEMBERHH	0.127***	0.127***	0.361***
	(0.016)	(0.016)	(0.055)
HOUSE_OWN	-0.023***	-0.023***	-0.200***
	(0.009)	(0.009)	(0.058)
HOUSE_SIZE	0.000***	0.000***	0.003***
	(0.000)	(0.000)	(0.001)
HEALTHCAREFACILITY	-0.002***	-0.002***	-0.011***
	(0.001)	(0.001)	(0.005)
PROVINCIAL DUMMIES	YES	YES	YES
N	295.155	295.155	295.155
WALD F STATISTICS	29.858	29.858	10.705

Note: All regression results produce an intercept but are not interpreted. *, **, ***: indicates significance at the 10%, 5% and 1% levels. Standard errors in parentheses

Source: Calculated from Susenas 2018, Podes 2018, and BPS 2018 by Authors.

5. CONCLUSION

Research on multidimensional energy poverty and its impact on health has not been widely conducted. Several studies that have been conducted provide empirical evidence that energy poverty has a negative relationship with health status. However, these studies only focus on one measure of energy poverty, not many have considered the multidimensional aspects of energy poverty. In fact, by considering the multidimensional aspects of poverty, the estimation results provided wide aspects and were more accurate than just one measure of energy poverty. This study used the multidimensional

aspects of energy poverty in Indonesia, as a developing country that has enormous natural wealth, including its energy potential, and analyzes its impact on health. Using a simultaneous equation model with 2SLS regression method, this study used the health complaint reports from each family member in the household to estimate the household health status. The results showed that households experiencing multidimensional energy poverty had lower health status, especially for people who live in remote areas with inadequate infrastructure. Energy deprivation both in accessibility and affordability dimensions also has a negative and significant impact to lower health status. Control variables that have negative and significant associations to health are the female household heads, the presence of family members with disabilities, lower level of education of household head, house size, and a large number of household members. Control variables that have positive and significant associations to health are employment status of a household, ownership of a house, and availability of healthcare facilities where households live.

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