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Where Do Energy-Poor Households Live? Empirical Evidence From Indonesia

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Abstract

Empirical analysis on the links between geography and energy access in archipelago setting is still limited. In particular, the territorial identification of energy poverty in Indonesia is still missing. Our study maps geographical location and estimates factors that determines the probability of being energy poor household in relation to electricity. We used the OLS (Ordinary Least Square) estimation and utilized the socioeconomic survey (Susenas) combined with data on terrain elevation, presence of geographic features such as mountainside, topography characteristics, ocean and forest obtained from the village census (PODES). The results show that energy poverty in Eastern part of Indonesia is larger than in the Western. In Eastern Indonesia, we estimate that 13.5% of the total households are energy poor compared to the Western which only 7.21%. Households located in the forest area was the dominant factor to influence prevalence of energy poverty among geographic constraints, with magnitude of influence at 22-23 percentage point to non-forest residents. Secondly, the presence of steep-sloped terrain is the next meaningful geographical constraint with contribution effect to energy poverty prevalence at around 18 percentage point. The result highlighted priority of locations in which resource and policy to reduce energy deprivation need to be allocated.

Key words : electricity, infrastructure, energy, poverty, households.

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INTRODUCTION

According to World Energy Outlook (2018), the proportion of the population with access to electricity reaches 89% of the population or roughly 840 million people living without electricity. A large portion of this population without electricity are in the geographically difficult locations. Indonesia is an archipelago country of over 18,000 islands and 82,190 villages with 267 million inhabitants in 2018. Based on data from Ministry of Energy and Mineral Resources (MoEMR), as of 2018, there are 507 villages unreachable by electricity. Access to electricity is widespread with relatively close to core regions such as Java and Bali. Geographic condition is one of the biggest challenges for government in providing electricity for outermost, remote and under-developed (3T) regions. According to MoEMR annual report in 2018, access to electricity is at 98% which uncover around 1,1 million households in access and use electricity.

Previous study from Sambodo & Novandra (2019), has examined correlation between energy poverty and its impact on people's welfare. Defining energy poverty as a condition when household electricity consumption below 32.4 kwh per month, Sambodo & Novandra (2019), study confirmed the well-known empirical link between electricity consumption and demand for a food. Advancing from the finding by Sambodo & Novandra (2019), who found that energy poverty makes socio-economic outcome worst (consumption and nutritional outcomes), this study maps where is the concentration of Indonesian energy poor household.

As an archipelago nation, geographic condition is the main obstacle aspect in providing equitable access of modern energy services in Indonesia. The lack of adequate infrastructure in peripheral regions could delay provision of energy access to maintain the wellbeing of households. Mainly there are two types of geographical remoteness to make electrification is challenging: remote small island and landlock-ness such as forest area. According to the Ministry of Forestry, forest cover share was about 92.3% of the total land area or equates to 86.9 million hectares in 2019. Of the 50% total forest areas are located in lagging region of Papua. Consider this abundance of the resource, on the supply side forest could be a driver for increased infrastructure cost and higher energy cost in Papua whereas on the demand side forest could be primary source of fuel and the commodity. Geographically land-constrained areas tend to make electrification expensive and associated with economic feasibility of electricity infrastructure development in Indonesia. Indonesia's as the largest archipelagic country makes it challenging to supply affordable electricity to certain areas.

Broadly, the influences of geography are critical importance in explaining the shape of electricity infrastructure development in Indonesia. The large variance of electrification rates between Eastern and Western can be explained by geographic features such as rural, mountainside, topography, ocean and forests as a barrier for government to provide electricity. Households who living in the least developed, isolated, and border areas (known as the 3T regions) are having poor electricity access compared to other developed areas. In 2018, the average of household electricity consumption per month was about 105.4 kwh per month in Eastern part, and 131.3 kwh per month in Western part.

There have been numerous studies at international context to link between geography and electrification. Regardless of the use of off-grid renewable, Burke & Kurniawati (2018), Oum (2019), Chaurey et al. (2004), and Dugoua, Liu & Urpelainen (2017), have underlined the relevance of geographical variation as economic fundamental in explaining energy access. Previous research has examined the correlation between relevance of given geography in Pacific ocean as a barrier to rural electrification (Dornan, 2014). Empirically, the regions with poor economic performance, underdeveloped regional economy, and remote geographical area have the highest case of multidimensional energy poverty (Mendoza Jr et al., 2019). Indonesia as the largest populous-archipelago country is an interesting context as the consequence of energy poverty issue involves millions of people. Therefore, identifying location and geographical factors to constraint energy poverty eradication is the upmost important analytical task in the topic. Thus, this study aims to (i) maps the locations of energy poverty prevalence, and (ii) estimate the influence of various geographical constraints to determine the probability of household becomes energy poor.

To perform the quantitative analysis of the two objectives above, we utilize two approaches. First, we measure the prevalence of household energy poverty with the formal definition used by Sambodo & Novandra (2019), with the national socioeconomic survey (Susenas, 2018). The resulting prevalence numbers then are mapped to district level visualization of the Indonesia with a standard Cartogram tools. We use tableau software to produce the map. This approach is standard technique, see for example application by (Hautdidier, 2015; Sanchez et al., 2020). Second, we employs a linear-Ordinary Least Square and a non-linear model of Probit estimates of household status being energy poor on several geographical constraint covariates in the form of categorical values, namely rural-urban, mountainside, topography, ocean, and forest area dummy.

The result of our mapping and energy poverty regression shows that that energy poverty in Eastern part of Indonesia is larger than in the Western. In Eastern Indonesia, we estimate that 13.5% of the total households are energy poor households with electricity consumption less than 32.4 kwh. This number is almost twice than the prevalence in the Western which only 7.21% of the total. Household located in the forest area was the dominant factor to influence prevalence of energy poverty among geographic constraints, with magnitude of influence at 22-23 percentage point to non-forest residents. Secondly, the presence of steep-sloped terrain is the next meaningful geographical constraint with contribution effect to energy poverty prevalence at around 18 percentage point. Our finding points to identification of locations and geographical constraints in which energy consumption deprivation issue need to be prioritized.

The rest of the sections are organized as follows. The next section describes the methodology. Then it followed by presentation of the results and discussion section. The last section is the conclusion.

RESEARCH METHODS

The first analysis in this study is the mapping of energy poverty prevalence in Indonesia at the district level. Accordingly the outcome variable of interest in this approach is energy poverty at the household level. Energy poverty in this study is defined as a condition in which total household electricity consumption per month below certain threshold. We follow the absolute cut-off of 32.4 kwh prescribed by (Sambodo & Novandra, 2019). At international standard, there has been variation of the absolute cut-off values, see for example include (Barnes et al., 2011; Foster et al., 2000; Goldemberg et al., 1988). They relate a deviation between actual energy access and an estimated basic minimum needs. We decide the use of cutoff at 32.4 for the following reasons. First, previous results from Sambodo & Novandra (2019), study confirm the well-known empirical link between electricity consumption and demand for a food. However, it has not fully constructed a causal link that geographical location plays an important role in affecting how remote an area from economic activity. The prevalence of energy poor household in each district (d), then defined by the following formula:

$$EP_d = 1/n \sum Ep_i \times 100 \quad (1)$$

In which EP_i is a dummy variable at the household level indicating the energy poor status based on the above cutoff definition. That is EP_i=1 if the total monthly household electricity consumption is less than 32.4 kwh and zero otherwise. We then map the values of EP_d that consist of 453 districts in 2018. The following map provide the locational distribution of energy poverty prevalence at district level in Indonesia in 2018.

The second empirical analysis is to estimate the probability of household to become energy poor conditional on some geographical constraints. We use geography data from village potential (PODES) to measure geographic constraints at the village level which then be aggregated at the district level. The coverage of geographical constraints is summit, downhill, valley, and other topography characteristics. We aggregate the figures at the district level by calculating the share of household living in each of categories of those geographical constraints. We presume that these geographical factors to be partly exogenous variables in explaining locational constraints with respect to supply side on energy poverty. To maintain the assumption holds, we try to limit the demand side contamination by limiting our samples to only individuals in the four bottom expenditure deciles. These deciles are known to be the domain for poor household in Indonesia.

The above strategy is based on the following considerations. The dependent variable of our study, energy poverty, can be characterized as functions of both supply-side driven by geographic constraints and these are associated with the cost of grid distributions; and as a function of demand side reflected by per capita consumption level. Theoretical literature in spatial economics development emphasize that access electricity is costly in remote areas Harrison (2013) and geography plays an important role, as well as distribution of population (Nordhaus, 2006). In our framework, geography factors in the main covariates are expecting to portray the affecting mechanism on how remoteness of a location influence supply side of electricity and thus economic activity.

To explain the regional characteristics on the probability of household becomes energy poor, we use the following multilevel estimating regression equation:

$$EP_i = \alpha + Geography_d\beta + X_i\gamma + \omega_i \quad (2)$$

EP_{id} is dummy variable that takes 1 if household i in district d has electricity consumption per month below 32.4 kwh, 0 otherwise. $Geography_d$ is vector of geography variables as the main explanatory variables (urban, mountainside, ocean, forest, and topography), aggregated at district level, X_{id} are set of control variables at household level (number of household members, and expenditure per capita), ω_{id} is the random error term. We add regional GDP (GRDP) and population as the proxy of economic activity measurement of the region as additional control variable. The initial hypothesis of this research is that all of those geographical constraints have a positive impact on the likelihood on household energy poverty status.

RESULTS AND DISCUSSION

The literature that discussed energy access, income and geography nexus have theoretized that lower income and the geographically difficult regions have a higher propensity to suffer energy poverty (Dornan, 2014; Dugoua, Liu, & Urpelainen, 2017). In this section, we present the results started by showing the descriptive analysis of income and energy poverty and then it followed by part explaining the identification of factor affecting energy poverty status by geography. First, we estimate household spending ability to analyze spatial distribution of economic activity. Using expenditure as a proxy for income, Table 1 displays the number of energy poor households in different expenditure per capita group. We use SUSENAS (2018), which cover 252,382 households to capture geographic boundaries and represent socioeconomic characteristics of households. We divide the distribution of households into ten groups. Our assumption for this estimation is that household consumption of electricity are increasing as income per capita rises.

Table 1. Share of Energy Poor Households to Total Households (SUSENAS, 2018)

Decile	Expenditure per capita HH (Rp)	Energy Poor HH (d=1)	Non-Energy Poor HH (d=0)	Share of energy poor HH to total HH (%)
1	83,286-404,326	7009	18230	27.7
2	404,327-519,515	5133	20105	20.3
3	519,519-624,289	4268	20970	16.9
4	624,293-744,200	3603	21635	14.2
5	744,200-886,297	3156	22082	14.3
6	886,305-1,058,742	2703	22536	10.7
7	1,058,745-1,264,083	2432	22806	9.6
8	1,264,085-1,572,713	1983	23255	7.8
9	1,572,737-2,160,595	1519	23719	6
10	2,160,624-62,086,416	1180	24058	4.6
		32.986	219.396	13

Note: HH refers to household.

Decile dispersion ratio is a simple and popular measure of inequality which presents the ratio of the average income or consumption of the richest 10% by that of the poorest 10%. The government's plan on the rural electricity development has increased the amount of household electricity consumption and reduced the gap between poor and non-poor energy households at remote areas.

This study use decile dispersion ratio measurement of the poorest (bottom 10%) and the richest (top 10%) to capture distribution information of expenditure per capita (spending ability). Based on the table 1, poorest household has the highest percentage of energy poor, approximately 27.7% of households were energy poor. This number decrease about 24.3% of the total energy poor households (52%) in 2008 at the same decile of expenditure per capita range. It can be found that per capita electricity consumption of energy poor household is lower than non-poor household. Decreasing the number of energy poor households into non poor households indicates that access of electricity tends to increase.

Interestingly, there are 4.6% of the richest household (decile 10) have electricity consumption below 32.4 kwh per month. As expected, household electricity consumption become increasingly significant in the richest decile of expenditure distribution. The results indicate that electricity consumption is highly correlated to regional income levels Karanfil & Li (2015), and the problem of energy to electricity in archipelago country was actually on the supply-side and correlated with geographic land constraint.

In addition to the data on expenditure, it is important to plot expenditure distribution by location, the most important reason for doing this is that economic density of a location. Table 2 reports the number of energy poor household based on region and poverty status. It shows the distribution of energy poor household due to geography characteristics between Eastern and Western. As the geography constraints increases, supply of electricity access is decreasing and positively influenced energy poverty. Apparently, there are considerable number of people living above poverty but experiencing energy poverty at almost 9%.

Table 2. Distribution of Population Based on Expenditure Per Capita Cut-Off Poverty Line, SUSENAS 2018 (Weighted)

	Below Poverty Line (%)	Above Poverty Line (%)	Eastern (%)	Western (%)
Energy Poor	19.8	8.7	17.3	8.3
Non-Energy Poor	80.2	91.3	82.7	91.7
Total	100	100	100	100

To calculate how many energy poor and non-energy poor household across groups, we divide population (252,382 households) based on their expenditure per capita referred as the lower (below cut off point) and the upper (above cut off point), combined with Eastern dummy. In an effort to show that household variation across region with different geographical conditions between Eastern and Western, Table 2 show that energy poverty are mainly concentrated in Eastern part of Indonesia. Of 19.8% total households live below poverty line in Eastern, 17.3% of the total households are energy poor households with electricity consumption less than 32.4 kwh. Compare to the Western, the number of energy poor households are larger at 7.21%, yet the percentage of energy poor households are only 8.3% of the total. This implies geography was one of the most important determinants of energy poverty in Indonesia. This finding is in line with previous research by Sambodo & Novandra (2019), that has examined correlation between energy poverty and its impact on people's welfare with range of energy poverty based on electricity consumption was about 22% of total households (SUSENAS, 2016). Eastern part of Indonesia cover 12 provinces include Papua, West Papua, East Nusa Tenggara, West Nusa Tenggara, Central Sulawesi, North Sulawesi, South Sulawesi, West Sulawesi, Southeast Sulawesi, Maluku, North Maluku, and Gorontalo.

The differences in the expenditure level between Western and Eastern Indonesia in Figure 1 indicates that most energy poor households located in the Eastern. The result is consistent with empirical evidence that there is a positive association between development level and electricity consumption (Bohlmann & Inglesi-Lotz, 2021; Burke & Csereklyei, 2016; Dong & Hao, 2018; Gregori & Tiwari, 2020; Pellini, 2021).

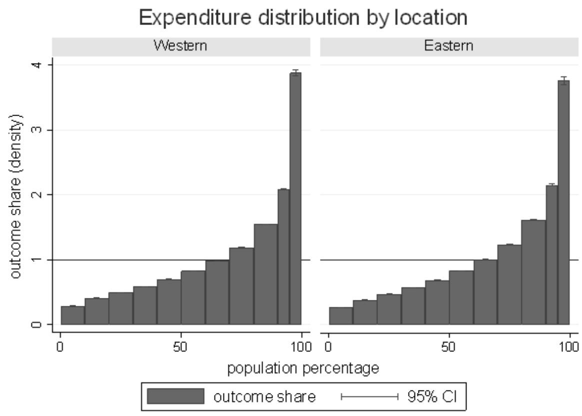

Figure 1. Expenditure Distribution at Different Percentiles by Location

Next, we want to see whether energy poverty distribution at the lowest and highest income group across provinces have similar pattern or not. Table 3 ranks top 5 provinces with the highest number of energy poor households and the lowest number of energy poor households. The results show that the number of energy poor household from Eastern provinces is distinctively higher than those from Western. This implies a positive association between energy poverty and geography. Household electricity consumption in unconstrained area (Western) is relatively higher than in constrained area (Eastern). East Nusa Tenggara, West Sulawesi, North Maluku, West Nusa Tenggara and West Papua are among the top five provinces with the highest number of energy poor households. Banten, Bangka Belitung Islands, DKI Jakarta, Bengkulu, South Sumatra are among the large provinces with the highest amount of households electricity consumption.

Table 3. The Percentages of Energy Poor Households to Total Households at the Lowest Income Group (Decile 1) and the Highest Income Group (Decile 10) in Selected Provinces

Top 5 provinces with the highest number of energy poor HH					
	East Nusa Tenggara	**West Sulawesi**	**North Maluku**	**West Nusa Tenggara**	**West Papua**
Decile 1	54	54.7	44	40	33.5
Decile 10	12	10.4	10.1	9.7	8

Top 5 provinces with the lowest of energy poor HH					
	Banten	**Bangka Belitung Islands**	**DKI Jakarta**	**Bengkulu**	**South Sumatra**
Decile 1	19.6	33.3	0	21.9	15.5
Decile 10	0.5	1.2	1.7	1.7	1.8

Table 3 shows that the share of energy poor households to total households in the lowest and highest income group are intuitively distributed among the best and worst performers at the provincial level. Among the top rich households (decile 10), the share of energy poverty-households are about twice in the provinces of East Nusa Tenggara, West Sulawesi, North Maluku, and West Papua which are on the list of the top highest percentage of energy poor households than the best performers of Banten, Bangka Belitung Islands, DKI Jakarta, Bengkulu and South Sumatra.

East Nusa Tenggara has the highest percentages at 12%. Based on recent data, electrification rate in this province reaches 62.07% that are close to 30% smaller than its neighbors electrification rate such as West Nusa Tenggara which is about 90.82% in 2018. West Papua with electrification rate of 90.47 has smaller percentages about 8% with electricity consumption below 32.4 kwh per month in upper group income. The results indicate provinces with low electrification rates tend to have higher percentage of energy poor households. Conversely, the province with the lowest percentage is Banten. Among the top rich households, only 0.5% households were categorized as energy poor. However, electrification rates in Banten have reached 100% since 2013 so in fact the results are consistent with the contents of regional economic development.

Table 4. The Influence of Geography on Energy Poverty (OLS Estimates For Selected Provinces)

	Dependent variable: Energy poverty status			
	Papua & West Papua	East & West Nusa Tenggara	Riau Islands	North Maluku
	(1)	(2)	(3)	(4)
Rural	1.564***	0.185***	0.567***	-0.085
	(0.560)	(0.051)	(0.191)	(0.098)
Mountainside	-0.028	0.066	-1.943***	-0.124
	(0.112)	(0.081)	(0.713)	(0.358)
Topography	0.207**	-0.090	0.267**	0.266*
	(0.094)	(0.084)	(0.112)	(0.141)
Ocean	0.044	-0.006	-2.959***	0.617***
	(0.062)	(0.045)	(1.023)	(0.127)
Forest	0.326***	-0.481	0.196	1.593***
	(0.093)	(0.463)	(1.253)	(0.595)
Observations	302	258	62	80
R-squared	0.382	0.632	0.903	0.794
Controls:				
Year dummies	YES	YES	YES	YES

From the analysis above, it can be found that there is certain relationship between electricity consumption and geography where the geography characteristics of each province are different. In Table 4, we try to analyze the influence of geography in all selected provinces that have the lowest electrification rates. The results on the Table 4% a difference influence of geography in the selected provinces. Empirically, energy poverty in Papua and West Papua tend to be positively correlated with forest location and topography at 32.6% and 20.7% respectively. Whereas the opposite pattern is apparent in West and East Nusa Tenggara. The coverage area in these provinces are mostly covered with hills and limestone mountains and consistent with the results. Moreover, ocean location has positive correlation on energy poverty in North Maluku and negative correlation in West Nusa Tenggara, East Nusa Tenggara and Riau Islands. Overall, the results suggest that Western electricity consumption is significantly higher than Eastern. However, this estimation does not include relevant controls and so the results can be overestimate. Hence, next we estimate an empirical model of the energy poverty with exogenous geography variables.

Figure 2. Distribution of Energy Poor Households at District Level, 2018

To assessing how influence geographic constraints in explaining energy poverty, we test association of each variable from the model in equation (2) with OLS estimate with the year 2018 data. Table 5 shows OLS estimation results on how well the explanatory variables explain the dependent variables. Based on OLS regression results, geography explains about 3.8-6.2% variation in energy poverty for 252,382 samples of household.

Table 5. The Influence of Geography on Energy Poverty at the Household Level

	Dependent variable: Energy poverty status		
	(1)	(2)	(3)
Elevation	0.017***	0.017***	0.017***
	(0.001)	(0.001)	(0.001)
Rural	0.089***	0.088***	0.069***
	(0.001)	(0.001)	(0.001)
Mountainside	0.056***	0.061***	0.056***
	(0.010)	(0.009)	(0.009)
Topography	0.135***	0.134***	0.125***
	(0.010)	(0.009)	(0.009)
Ocean	0.068***	0.081***	0.087***
	(0.003)	(0.003)	(0.003)
Forest	0.126***	0.149***	0.178***
	(0.013)	(0.013)	(0.012)
Observations	252,382	252,382	252,382
R-squared	0.038	0.048	0.062
Controls:			
Households Size	NO	YES	YES
Expend per Capita	NO	NO	YES

*Notes: OLS estimates of geography influence on energy poverty using electricity consumption dummies. We try to explain the changes of energy poverty (dummy that takes 1 if electricity consumption per month below 32.4, and 0 otherwise). Each column shows the coefficient of the variable of reference on energy poverty and its associated standard error appears in parentheses. *** p<0.01, **p<0.05, *p<0.1.*

At household level, we use socio-economic survey of SUSENAS (2018), that consist of 252.382 households to analyze the influence of geographical factor on energy poverty in Indonesia. In general, the results demonstrate that geographic constraints were strongly associated with energy poverty. All geography variables in Table 5 statitically significant at 1% level. Topography and forest coefficients have stronger correlation on energy poverty compared other components of geography, it contributes 12.6-17.8% of the variation on energy poverty. Furthermore, increasing a number of households by 1% in sloping area, then the predicted energy poverty increases by 12.5% for every additional number of households in slope area. After adding controls, the share of households living inside the forest area contribute significantly up to 17% addition in energy poverty.

CONCLUSION

The discussion of the energy policy with territorial or spatial development strategy emphasized that infrastructure development is costly, and thus identifying geographical priority plays an important role in advancing energy access for all and in particular to reduce energy poverty incidence. Recent empirical evidence that identify such locations in the developing country context such as Indonesia with archipelagic setting has been scant. This paper offer a novel analysis to addresses this gap in the literature. This study aims to map concentration of household living with energy poverty and to provide empirical estimate of geographical factors that matters with the energy poverty status. Combining multiple source of dataset from household surveys, village survey and district level variables, we found that Indonesia's energy poverty concentrated in the Eastern part of the country. This finding is not surprising as the Eastern part is more geographically constrained than the Western part. Moreover, the results indicate that problem of electricity access in Indonesia are more toward on the supply-side and correlated with geographic conditions. As land constraints increases, supply of electricity access is decreasing and positively influenced energy poverty. In Eastern part of Indonesia, the presence of difficult topography and forest area could potentially exaggerate the incidence of energy poverty across all districts. The estimate show that for every three household, one of them is energy poor when they live in forest area than they are not. Nevertheless, our study is limited to identification of geographical concentrations of the energy poverty-households and did not cover details of analysis on how to address the issue with peculiar policy. We leave it as future works in the area.

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