Energy equity analysis in Metro Manila using household expenditure data

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Abstract. Energy poverty in the Philippines has been prevalent, but current energy equity metrics in the Philippines are done only on a national level. Lorenz curve and Gini coefficient are concepts traditionally applied in economics to measure wealth inequality. In this paper, the authors will adapt the methodology used by Jacobson to measure energy inequality in Metro Manila for 2015 using energy expenses of households retrieved from the Family Income and Expenditure Survey conducted and published by the Philippine Statistics Authority every three years containing energy expenses, income, and socio-economic identifiers of a household. The main energy resources listed in the survey are electricity, LPG, kerosene, fuelwood, charcoal, and biomass residue. To translate energy expenses to energy consumption, historical costs available from public records are used in conjunction with the fuels' calorific values. From there, Lorenz curves and Gini coefficients are calculated for districts and cities in Metro Manila. Further comparison reveals the relationship of income and energy consumption Gini coefficients in the region. Based on the results, the authors include recommendations to improve the use of Lorenz curve and Gini coefficient as a metric in quantifying energy equity.

1. Introduction

One of the major global problems being faced today is energy poverty. It can be defined as the inability to acquire modern energy services, which can be in the form of cooking, lighting, transport, and many others. This inability to access energy can lead to adverse consequences on people’s health, social activities, education, and overall quality of life.

Various approaches have been done in recent years to further analyze energy poverty. One example is the integrated approach by Che et al, generating an indicator system and assigning weights by rough set and a large-scale survey [1]. Their study also presented a global assessment of the existence of energy poverty in 125 countries. Another study conducted by Scarpellini et al used spatial analysis of energy poverty in Spain in conjunction with a statistical analysis of related financial aids provided to households. The authors found that energy poverty is less acute in rural households in the region [2]. Meanwhile, a study on the effect of government energy efficiency programs to energy poverty in Alaska is conducted by Pride et al [3]. Petrova, on the other hand, examined the effect of energy poverty on the consumption of light and the overall quality of life of the people [4]. Finally, an analysis on the connection between urban form and city densification to energy equity was considered by Poruschi and Ambrey in Australia [5].

Measurements such as kilowatt-hour (kWh) per capita or kWh/GDP may be used to measure economic performance of a country, but there is no consensus as to what the most efficient way is in...
assessing the corresponding energy poverty. Over the past years, several attempts to quantify energy equity have been done by researchers. Templet in 1994 defined energy equity as the ratio of energy prices of the residential sector to the industrial sector [6]. Hall et al had a more comprehensive scope, defining energy equity as equality in terms of access to affordable, safe, and reliable energy, and the distribution of the risks and benefits of new technology [7]. Moreover, Adams and Bell limit their definition to three key issues: the distribution of impacts, responsibility, and costs and benefits [8]. From an interesting perspective, Kemmler and Spreng proposed the use of energy-based indicators to measure poverty and equity in a country [9]. While the existing literature on energy equity is largely from a social science standpoint, Jacobson et al introduced a quantitative perspective by using the Lorenz curve and Gini coefficient in the analysis of energy distribution through parallel case studies in Norway, USA, El Salvador, Thailand, and Kenya [10]. The Lorenz curve and Gini coefficient have been developed and traditionally used to analyze wealth distribution in countries.

The Philippine economy has been steadfastly growing in recent years. In fact, the country recorded a Gross Domestic Product (GDP) growth of 5.9% in 2015, next only to India at 7.3%, China at 6.9%, and Vietnam at 6.7%. That same year, the six-year moving average of real GDP growth was recorded at 6.2%, its highest since 1978 during that time [11,12]. Philippines’ National Capital Region (NCR) or more known as Metro Manila, also recorded a high regional growth of 6.6%, while having the highest contribution to the national growth with 2.4 percentage points. NCR also had the largest share of the country’s GDP with 36.5% in 2015 [12].

Despite the growing national economy, energy poverty in the Philippines remains. According to the 29th EPIRA Status Report published by the Department of Energy (DOE), the national electrification rate reached 89.61% in 2016, leaving approximately 2.4 million Filipinos with no access to electricity [13]. This is close to figures found in the 2016 Annual Poverty Indicators Survey (APIS) Report published by the Philippine Statistics Authority (PSA), indicating that 91.4% of families in the country had access to electricity [14]. The report also indicates that only 79.8% of the total households belonging to bottom 30% income earners had electricity connection, while 96.4% of the top 70% had electricity connection. These numbers suggest that the level of income affects electricity distribution among families in the country. However, a study looking at the socio-economic aspect of energy consumption in the Philippines, specifically in Metro Manila, using household data is yet to be conducted. Severe inequity in energy use in the country is evident, but there is currently no means to assess its degree and scientific evidence to influence policy. This paper aims to quantify and assess the energy poverty in Metro Manila by calculating the Gini coefficients and providing the Lorenz curves using the household energy expenditure data extracted from Family Income and Expenditure Survey (FIES) report published by PSA.

The study shall cover only Metro Manila and will be analyzed on city and district levels using household data. The data to be used will be derived from the FIES report for year 2015 [15]. FIES is conducted in the Philippines every three years and serves as the key source of data on family income and expenditure, indicating the levels of consumption by item of expenditure and sources of income. FIES divides households into categories, from the region, the district, the city, up to the barangay that it belongs to; however, for this study the energy consumption distribution will be analyzed on city level only. That is due to several barangays having only one participant in the survey; thus, analysis on barangay level cannot be done. PSA defines barangay as the smallest political unit in the country, usually having an enumerator assigned for identification [16].

2. Methodology

FIES provides energy expenses per household. These expenses can be classified under direct fuel purchases or indirect fuel expenses. Direct fuel expenses for LPG, kerosene, fuelwood, charcoal, and other fuels are indicated separately in the FIES. Expenses pertaining to fuel directly burned by the households may be converted to energy units by dividing with the historical fuel price per liter or kilogram and multiplying it to the calorific values of corresponding types of fuel, such as in [17]. Expenses pertaining to indirect fuel consumption such as electricity will be divided by the historical cost
per kilowatt-hour (kWh). The calculated energy consumption per household for these expenses shall then be used to measure energy distribution by calculating the Gini coefficients and plotting the Lorenz curves. Results will then have to be analyzed and compared to the prevailing economic and energization conditions of the region. A simple block diagram showing the conceptual framework of this study is provided in Figure 1.

![Figure 1. Conceptual framework for energy equity analysis.](image)

### 2.1 Energy Consumption Calculation

Electricity and fuel historical costs are important in accurately quantifying the energy consumption in a region. Unfortunately, most of the data provided by the government publicly are already aggregated and might not account for the variability of the costs relative to time. Requests for unaggregated data are limited, if not totally inaccessible to the public due to laws surrounding data privacy.

#### 2.1.1 Electricity

In this study, it is assumed that the electric consumption of all households included in the FIES for Metro Manila are supplied by Manila Electric Railroad and Light Company (MERALCO) which is the sole utility distribution company in the region. Due to varying subsidies given by the company to households with low consumption (0–100 kWh) mandated by the government, as well as the varying taxes imposed for specific consumption ranges, assuming one average annual price point for electricity will not give an accurate account of the energy used in a household. Fortunately, the company provides the unaggregated data used to calculate the monthly price point per kWh of a specific consumption range.

To simplify calculations, the authors assumed that each household utilizes the same amount of power per month. The first step in quantifying energy use is to find within which consumption range a household’s electricity expense falls. These can be seen on Table 1. Once determined, the corresponding consumption can be obtained using equation (1).

\[
EC = 12 \cdot \frac{E - B}{A + C} \text{ kWh/household}
\]

where:

- \( EC \) = Annual electricity consumption per household, kWh/household
- \( E \) = Actual annual electricity expense per household, Php/household
- \( A \) = Partial annual rate per kWh, Php/kWh/household
- \( B \) = Partial annual rate per household, Php/household
- \( C \) = Energy tax factor

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1. As confirmed by Distribution Utility Map provided by Philippine Energy Regulatory Commission online at https://www.erc.gov.ph/ContentPage/374
2. MERALCO posts the typical household consumptions for each month, as well as the specific charges and taxes for the month which are used to calculate for the historical costs online at https://company.meralco.com.ph/news-and-advise/rates-archives
Table 1 shows which values to use for equation (1) to calculate the energy consumption. E is the actual annual electricity expense for each of the households included in the 2015 FIES. Values for A, B, and C reflected on the table are calculated using the unaggregated data from MERALCO.

Table 1. Derived variables for energy consumption calculation.

| Consumption per household (kWh/household) | Electricity Expense per household (Php/household) | Partial Annual Rate per kWh ((Php/kWh)/household) | Partial Annual Rate per household (Php/household) | Energy Tax Factor |
|------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------|
| min                                      | max                                           | min                                           | max                                           | A               |
| 0                                        | 20                                           | 67.50                                         | 128.13                                        | 3.03            |
| 21                                       | 50                                           | 1,343.76                                      | 2,987.00                                      | 56.66           |
| 51                                       | 70                                           | 3,911.20                                      | 5,293.81                                      | 72.77           |
| 71                                       | 100                                          | 6,536.21                                      | 9,133.57                                      | 88.87           |
| 101                                      | 200                                          | 11,598.20                                     | 22,665.16                                     | 111.79          |
| 201                                      | 300                                          | 23,692.43                                     | 35,210.30                                     | 116.34          |
| 301                                      | 400                                          | 36,620.33                                     | 48,563.70                                     | 120.64          |
| 401                                      | 500                                          | 51,686.38                                     | 64,370.90                                     | 128.13          |
| 501                                      | 650                                          | 64,499.02                                     | 83,589.87                                     | 128.13          |
| 651                                      | 1000                                         | 83,719.19                                     | 128,854.13                                    | 128.13          |
| 1001                                     | 1500                                         | 128,984.65                                    | 194,117.36                                    | 128.13          |
| 1501                                     | >1501                                        | 194,249.69                                    | over 194,250                                  | 128.13          |

In actual conditions, monthly power consumption of a household may vary due to several external factors. One of these factors is climate, wherein months in the summer season tend to increase energy use, while colder months tend to decrease the energy use. This may result in a household’s annual electricity expense to not fall within any range initially calculated. Estimating the equivalent energy consumption for these households may be calculated by interpolation between consumption ranges in relation to electricity expense which is also provided in Table 1. Lastly, since it is indicated in the FIES if the household is connected to an electricity provider, data cleaning may be done as well. Households which are indicated to have no electricity connection but have expenses for electricity shall have an equivalent of zero (0) kWh consumption instead.

2.1.2 LPG, kerosene, fuelwood, charcoal, and bagasse The authors were able to request for the historical cost data on LPG, kerosene, and bagasse through the Freedom of Information (FOI) online facility. For LPG and kerosene, the average price per month in the given year was provided. Based on this, the price point averages of respective fuels for 2015 are computed, as reflected on Table 2. Also included in the FIES is the expenditure for household fuels not specifically identified in the survey form. To quantify the energy consumption for this expense, the authors assumed the fuel to be bagasse, a form of biomass residue, in accordance with the Household Energy Consumption Survey (HECS) conducted in 2011 by the DOE, where it was reported that 22.3% of households in the Philippines used biomass residue as one of their fuels at home in that year [18]. DOE, through the FOI facility, was able to give only the price range of bagasse from monthly generation reports of existing biomass powerplants. Despite this limitation, the authors decided to use the midpoint of this price range to account for the energy consumption of this fuel type for this study.

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3 Data not publicly available can be requested at Freedom of Information Facility. Access to the historical data for fuels utilized by the authors is listed. For LPG:
http://www.foi.gov.ph/requests/aglzfmVmb2ktcGhyHQsSB0NvbhnRlbnQiEERPRS0xMTE5ODA4MjMjMyNzI4M
For kerosene at:
https://www.foi.gov.ph/requests/aglzfmVmb2ktcGhyHQsSB0NvbhnRlbnQiEERPRS04NzgzMDQyMzEwMzMzEM
For bagasse at:
https://www.foi.gov.ph/requests/aglzfmVmb2ktcGhyHQsSB0NvbhnRlbnQiEERPRS0yMTI1OTY2MTE5MjYM
The average retail prices per cubic meter (m$^3$) of fuelwood and per sack of charcoal for each region in the Philippines were provided in the 2015 Philippine Forestry Statistics published by the Forestry Management Bureau of the Department of Environment and Natural Resources (FMB-DENR) [19]. The methodology from Wood Fuel Surveys Report commissioned by the Food and Agriculture Organization of the United Nations (FAO UN) is used to convert these units to per unit mass [20]. The mass calculated is then further converted to energy units using conversion table provided by DOE\footnote{DOE provides basic energy conversion table at: https://www.doe.gov.ph/units-measurement-and-conversion-table}. Table 2 shows the price points per unit derived from the various extracted data, as well as the corresponding calorific values of the different fuel types based on DOE’s energy conversion table which can be used for calculating the respective fuels’ energy consumption in Equation (3). Fuel expenditure per household ($e$) is given in FIES.

$$EC = \frac{e_i}{p_i} \times CV_i \text{ kWh/household;}$$

where:  
EC = energy consumption of a household for specific fuel type, kWh/household  
$e$ = expense of a household for specific fuel type $i$, Php/household  
$P$ = price per unit of specific fuel type, Php/unit  
CV = calorific value of specific fuel type, kWh/unit

| Fuel type   | Unit    | Price (Php) | Calorific Value (kWh) |
|-------------|---------|-------------|------------------------|
| Kerosene    | liter   | 50.34       | 9.29                   |
| LPG         | liter   | 26.28       | 6.74                   |
| Charcoal    | kilogram| 8.45        | 6.98                   |
| Fuelwood    | tonne   | 1,142.38    | 3,826.27               |
| Bagasse     | tonne   | 2,500.00    | 4,954.38               |

2.2 Lorenz Curve and Gini Coefficient

Lorenz curves and Gini coefficients are concepts in economics traditionally used to graphically represent the income inequality of a given population. Jacobson et al utilized the Lorenz curve and Gini coefficient to quantify energy poverty in five countries: Norway, USA, El Salvador, Thailand, and Kenya – with Norway having the least measured energy poverty [10]. Adapting Jacobson’s methodology to measure energy equity, the Lorenz curve will be defined as a ranked distribution of the cumulative percentage of the population for NCR represented in the FIES 2015 on the x-axis, against the cumulative percentage of energy resource consumption distributed along the y-axis. Perfect equity is shown by a 45-degree diagonal line which extends from the origin to the point with coordinates of cumulative percentage population, $x = 100\%$; and cumulative percentage energy resource $y = 100\%$. The greater the distance of the actual curve to the perfect equity line, the greater the inequality in energy consumption. The distribution can be measured numerically by calculating the Gini coefficient of the corresponding Lorenz curve. The Gini coefficient measures the difference between a uniform distribution and the actual distribution of a resource. It is the ratio between the area enclosed by the diagonal line and the Lorenz curve and the total area under the diagonal line of uniform distribution. The adapted formula from Jacobson et al is shown in equation (3).

$$G_e = 1 - \sum_i (Y_{i+1} + Y_i)(X_{i+1} + X_i);$$

(3)
where:  
\[ Ge = \text{Gini coefficient} \]
\[ Xi = \text{the number of energy users in population group } i/\text{total population} \]
\[ Yi = \text{the quantity of energy used by population group } i/\text{total energy use} \]

Before proceeding with the calculations, \( Yi \) must be ordered from lowest to highest consumption. Values for the Gini coefficient are from 0 to 1, with the value of 0 indicating perfect equity – as represented by the 45-degree diagonal line mentioned earlier. A value of 1 is indicative of complete inequity.

Lorenz curves are not able to give a direct measurement of different utility services, but they can measure quantitatively the differential amounts of energy consumption. That is, when given with the same amount of energy, a household may consume it differently in various forms of services such as lighting, heating, or powering appliances. The variations in amount of energy consumption can also be a result of the different efficiencies of the different technologies used for specific services. If the average overall efficiency among consumers can be assumed constant, as in the case of MERALCO providing electricity for Metro Manila, then quantities of energy can be considered a reasonable measure of utility. Same can be assumed when a unit of energy’s marginal benefit is consistent from consumer to consumer.

It should also be noted when these given conditions do not hold. For instance, using fuelwood or charcoal for cooking requires a greater amount of energy than when using LPG. In this situation, the lower level of energy consumption is preferred between the two. Energy consumption can be measured quantitatively to estimate energy equity in situations with which a single energy source is considered, or where there is constant average conversion efficiency per user.

3. Results Discussion

As mentioned in the previous section, respective energy consumption due to different energy sources cannot be added up quantitatively, unless efficiency is assumed constant as in the case of residential electricity consumption. It will be greatly inaccurate to simply just add up the respective energy consumption of a household calculated from the energy expenses in FIES. An illustration of this are households utilizing fuelwood for cooking versus households using electricity for the task. The smaller amount of energy needed to cook by using electricity might be misrepresented as an inequality. Thus, the authors decided to measure the Lorenz Curve and Gini coefficient for electricity consumption only.

The method in determining the energy consumptions for fuels other than electricity is still presented, as data concerning the efficiency of an energy resource might emerge in the future.

| Region/District City/Municipality | Income Gini Coefficient | Energy (Electricity) Gini Coefficient | Total annual income per capita | Total annual electricity consumption per capita | % of population with income per capita lower than x | % of population with electricity consumption per capita lower than y |
|----------------------------------|-------------------------|--------------------------------------|-------------------------------|-----------------------------------------------|---------------------------------|-----------------------------------------------|
| NCR                              | 0.53                    | 0.53                                 | 92,870.61                     | 2,619.23                                      | ≤ 65%                           | ≤ 94%                                          |
| District 1                        | 0.50                    | 0.50                                 | 89,267.25                     | 2,640.44                                      | ≤ 67%                           | ≤ 92%                                          |
| City of Manila                    | 0.50                    | 0.50                                 | 89,267.25                     | 2,640.44                                      | ≤ 67%                           | ≤ 92%                                          |
| District 2                        | 0.53                    | 0.53                                 | 95,478.75                     | 2,800.50                                      | ≤ 67%                           | ≤ 94%                                          |
| City of Mandaluyong               | 0.45                    | 0.03                                 | 81,640.13                     | 1,793.51                                      | ≤ 63%                           | ≤ 96%                                          |
| City of Manila                    | 0.46                    | 0.06                                 | 71,266.18                     | 1,355.85                                      | ≤ 64%                           | ≤ 96%                                          |
| City of Pasig                      | 0.53                    | 0.53                                 | 81,733.98                     | 1,722.92                                      | ≤ 69%                           | ≤ 95%                                          |
| City of Quezon                    | 0.52                    | 0.02                                 | 94,095.16                     | 2,424.90                                      | ≤ 68%                           | ≤ 94%                                          |
| Quezon City                       | 0.55                    | 0.06                                 | 103,855.13                    | 1,785.11                                      | ≤ 68%                           | ≤ 94%                                          |
| District 3                        | 0.46                    | 0.03                                 | 77,871.86                     | 1,234.19                                      | ≤ 65%                           | ≤ 96%                                          |
| City of Cainta                    | 0.46                    | 0.03                                 | 56,133.83                     | 1,399.01                                      | ≤ 65%                           | ≤ 96%                                          |
| City of Malabon                   | 0.46                    | 0.03                                 | 71,541.14                     | 1,476.53                                      | ≤ 66%                           | ≤ 97%                                          |
| City of Navotas                   | 0.48                    | 0.50                                 | 73,242.56                     | 328.40                                        | ≤ 70%                           | ≤ 91%                                          |
| City of Valenzuela                | 0.45                    | 0.03                                 | 88,374.94                     | 1,356.38                                      | ≤ 65%                           | ≤ 94%                                          |
| District 4                        | 0.56                    | 0.04                                 | 109,205.52                    | 2,763.81                                      | ≤ 69%                           | ≤ 91%                                          |
| City of La Pintos                 | 0.60                    | 0.04                                 | 91,379.05                     | 3,466.06                                      | ≤ 79%                           | ≤ 98%                                          |
| City of Malaki                    | 0.63                    | 0.00                                 | 101,579.74                    | 2,519.99                                      | ≤ 67%                           | ≤ 88%                                          |
| City of Manila                    | 0.52                    | 0.07                                 | 95,656.16                     | 2,236.42                                      | ≤ 66%                           | ≤ 97%                                          |
| City of Pasig                      | 0.62                    | 0.98                                 | 116,974.14                    | 2,367.27                                      | ≤ 74%                           | ≤ 92%                                          |
| City of Quezon                    | 0.48                    | 0.03                                 | 82,323.13                     | 2,427.10                                      | ≤ 65%                           | ≤ 92%                                          |
| Pasig City                        | 0.63                    | 0.04                                 | 103,626.51                    | 4,656.14                                      | ≤ 65%                           | ≤ 85%                                          |
| Municipality of Patnalos          | 0.60                    | 0.06                                 | 128,870.09                    | 3,287.63                                      | ≤ 74%                           | ≤ 90%                                          |

Table 3. Income and energy Gini coefficients, annual income per capita, annual electricity consumption per capita.
Table 3 shows the Gini coefficients calculated for Metro Manila or National Capital Region (NCR) and the districts and cities belonging to the region. The table also includes the respective income and electricity per capita, as well as the percentages of the population having lower income and electricity than the computed total, respectively.

The income Gini coefficient computed in this paper is different from the income Gini coefficient of 0.3909 included in the FIES report for 2015 [11]. That is because the x-axis used for the Lorenz curve graph is the percent cumulative number of households and the y-axis is percent cumulative income for FIES 2015. In this study, it is assumed that electricity consumption in a household is distributed equally for each member, and the abscissa and ordinate for the Lorenz curve graphs and the computed Gini coefficients utilize computations per capita to further illustrate the existing inequality. The computed Gini coefficients for electricity are much closer to 1 than the coefficients for income. Further comparison of the results to the national electrification rate of 88% in 2015 [21] shows despite being connected to available energy infrastructures, many households are still not able to fully utilize electricity as their main source of energy, with more than 80% of the surveyed households still relying on other sources of energy to do household cooking, lighting, and other services. Another indicator of the uneven distribution of both income and energy is the large population percentage having lower income and energy income per capita than the average. Individual results for this can be seen on Table 3.

Figure 2 shows the Lorenz curve for the income inequality in NCR and its districts. Figure 3 shows the energy Lorenz curve for the electricity inequality in NCR and its districts. Notice in the figures that for a given income Gini coefficient, the corresponding energy (electricity) Gini coefficient is higher.

To confirm the relationship between income and energy distribution, a graph of cumulative income vs cumulative energy consumption per capita is shown on Figure 4. It can be seen from the figure that for a household to have a unit increase in electricity consumption, it should have an increase in income, indicating significant correlation between said variables.
4. Conclusion
In this study, the energy equity in the Philippines is measured using the Lorenz curve and Gini coefficients with household energy expenditure data source from Family Income and Expenditure Survey conducted by the Philippine Statistics Authority.

The authors were able to describe a methodology to convert household expenditure data into energy use. However, one serious limitation of the Lorenz curve and Gini coefficient is that you can only use this for energy resources with either constant efficiency or when efficiency of a technology employed for a specific energy resource is known. Because of this, energy consumption calculated from the methodology presented for other fuel types such as LPG, kerosene, and bagasse can only be used once the utilization level of energy services such as cooking, lighting, and others are known for each energy resource.

Despite the growing economy of the Philippines, specifically Metro Manila, resulting Gini coefficients and graphed Lorenz curves imply poor distribution of electricity among households in the region. The resulting Gini coefficients for the whole NCR and its districts do not vary much, ranging from 0.82 to 0.85 for energy and 0.46 to 0.56 for income. Looking at the city level, the calculated Gini Coefficients are more varied, ranging from 0.50 to 0.90 for energy and 0.42 to 0.65 for income. Even with relatively high electrification rate in the country, expenditure data from FIES imply that low income households still rely on other energy resources aside electricity for different services. It should also be noted that a low Gini coefficient does not immediately mean good energy equity. Results show that regardless of having a low energy coefficient of 0.50, the city of Navotas also has the lowest electricity consumption per capita. Thus, careful consideration should be done to properly assess the energy equity of an area in relation to the available data. Additionally, the graph of income vs electricity consumption distribution suggests that a household’s electricity utilization can be dependent on its level of income.

Further studies should be done to investigate energy equity corresponding to certain time periods in order to show periodical comparisons. This should provide insights on the electrification progress of the country versus the periodical changes in distribution of energy. Currently, there are no studies setting the standard of acceptable values for energy Gini coefficients; thus, further analysis should be done to examine the relationship of Lorenz curve, Gini coefficients, and the quality of life of people. This should help decision makers in crafting policies for better energy distribution in the country. Lastly, additional studies should be done in order to integrate the different consumption of sources of energy so as to improve the Gini coefficients and Lorenz curves produced in this study.

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