Characteristics and Significance of Residential Density and Energy Consumption in Surabaya, Indonesia

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ABSTRACT— *Residential activities have significant impact on energy use. Those activities vary among residential densities. Surabaya classified its city density into three category, those are low, medium and high. This paper aims to explore the characteristics and significance of residential density and energy consumption in Surabaya City, Indonesia. The selected study areas were chosen from the classification of population density based on Surabaya Spatial Plan. The first step of this research is to calculate the energy consumption in each residential density. The next step is to analyze the significant correlation of residential density attributes and energy consumption. The result showed significance difference in five residential characteristics, in terms of number of vehicle ownership, housing ventilation, electricity use, cooking fuel use and use of electronic devices.*

Keywords— energy consumption, household behavior, population density, residential density

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1. INTRODUCTION

Cities are considered as engine of growth. Population growth that occurs in cities will have a direct impact to the necessities of life. Some of the necessities require energy consumption. In household, energy is required for daily activities such as cooling, heating, lighting, washing, cooking and others. The amount of energy consumption per household may vary based on lifestyle, climate and type of residence.

Urban form is an important element from each planning process. A good understanding of relation among city structure, energy and environment is essential in the formulation of strategy that can be taken to overcome the environmental problems [1]. Before formulating good strategies, it is required to identify the characteristics of residential, their activities related to energy use as well as their behavior in using the energy.

Increase in energy use in residential is related to development of housing consumption [2]. There exist several factors that influence the development, such as income, number of members and ethnic background [3]. The household sector in Indonesia has significant contribution to the national energy consumption [4]. The use of energy in housing gives the biggest contribution to greenhouse gas emissions, especially CO_2 emission [5]. This condition is expected to increase in the future [6].

Population density in urban area can be counted through three approaches, i.e. administrative population density, urban population density and housing population density [7]. Administrative population density is also known as overall population density or arithmetic population density. Administrative population density is the ratio between the numbers of people who live in certain administrative region with vast administrative area concerned. Surabaya is one of metropolitan cities in Indonesia. Based on the Spatial Plan, there are three classifications of population density; those are high, medium and low density. Based on the Preliminary Identification Report of Surabaya Spatial Plan 2009, it is stated that there are three classifications of population density, i.e. high density: > 250 population per hectare; medium density: 150 to 250 people per hectare; and low density: < 150 people per hectare [8].

Residential characteristics can be categorized into several aspects, such as physic, social, legal and economic. The physical aspect relates to the land area, supporting facilities based on the ratio between the family members and the housing area. The social aspect indicates the education level, health factor, social relationship as well as the socio environment. The legal aspect indicates the land status, while the economic aspect relates to the job or employment [9].

1.1 Problem Statement

Household activities have significant contribution to energy consumption. These activities are also affected by lifestyle. Surabaya is the second largest metropolitan city in Indonesia.

In general, the higher the residential density level, the higher the energy consumption. This paper is part of a research that focused on the correlation of residential density to carbon emission in Surabaya City [10]. In this paper, the level of energy consumption in each residential density was observed and the significance of each variable was determined respectively.

1.2 Scope of Study

This study focuses on residential density and energy consumption. The density is classified into three classifications based on Surabaya Spatial Plan. The respective case study area was selected based on population density that represents each type of residential densities. The density value refers to administrative population density. The chosen study area is explained as follow:

- Low residential density: Jambangan District
- Medium residential density: Genteng District
- High residential density: Tegalsari District

Energy consumption is calculated from household energy use, including cooking fuel consumption, vehicle fuel consumption and electricity use of household equipment or devices.

2. MATERIAL AND METHODS

This research is classified as quantitative research. The required data was collected through primary and secondary surveys. The primary survey was carried out through questionnaire in order to gather the housing characteristics, including social and economic aspects of the household. The secondary survey was carried out in order to understand the characteristic of the city by looking at the city statistical data, city spatial plan and other related data.

2.1 Selecting the Case Study Area

Surabaya City consists of 33 districts. The population density in each district varies from low to high density. In this research, the density of residential is determined from the population density. Therefore it is required to select districts with similar total area. Among 33 districts, there are three districts with similar total area, i.e. more than 400 Ha.

Table 1: comparison of population density of the selected case study

No.	Districts	Total Area (Ha)	Total Population (inh)	Density (inh/Ha)
1.	Tegalsari	429.38	119,471	278.24
2.	Genteng	404.75	69,691	172.18
3.	Jambangan	418.62	42,961	102.63

Source: Adapted from Identification Report of Surabaya Spatial Plan, 2009

2.2 Quantitative Descriptive Analysis

Quantitative descriptive analysis will describe the condition of residential density in each density classification in the form of frequency distribution table or simple frequency distribution and is completed with a form of bar charts or graphs and line diagrams.

2.3 Cross Tabulation Analysis

Cross tabulation was used to analyze the significance of differences of energy consumption in each residential density. The use of crosstab in this research is part of the research that examines the correlation between residential density and carbon emission in Surabaya City. Hence, the step of cross-tab analysis here is limited to the description of significance value. The significance of the difference between energy consumption and type of residential density was assessed by using Pearson's chi-squared test. The significance level used in this cross tabulation analysis is 90%.

The purpose of cross-tabulation analysis of the energy consumption characteristics of the household sector in each residential density is to determine whether the energy consumption is significantly different in each residential density. By looking at the differences in each residential density characteristics, it is expected that the types of energy consumption can represent the character of the residential density, whereas the characteristic is shown from the household income, expenditure and energy consumption behavior in each residential density.

3.   RESULT AND DISCUSSION

3.1 Characteristics of Energy Use in Each Residential Density

In order to identify the characteristics of energy use in each residential density, a number of questionnaires were distributed. The questions are related to four aspects, those are economic characteristic, housing characteristic, energy usage and individual behavior related to electricity devices.

Table 2: Household characteristics

No.	Aspects	Variables
1.	Economic characteristics	• Monthly income • Monthly expenses • Purposes of monthly expenses • Number of family members • Number of car ownership • Number of motorcycle ownership
2.	Housing characteristics	• Building condition • Land area • Building area • Number of floors • Housing function • Ventilation
3.	Energy usage	• Use of daylight • Use of electricity power • Monthly electricity consumption/use • Use of vehicle • Use of cooking fuel
4.	Individual behavior related to electricity devices	• Time to use cooking equipment • The way to use electricity devices

The results show that the average and total energy consumption differs from low density to high density [10].

Table 3: Average household energy consumption per month based on residential density

No.	Density Type	Average Energy Consumption			
		Electricity (kWh)	Vehicle Fuel (Liter)	Cooking Fuel LPG (Kg)	Cooking Fuel Kerosene (Liter)
1.	High Density	267.63	49.98	11.20	10.00
2.	Medium Density	235.25	46.38	10.30	14.00
3.	Low Density	239.57	52.51	10.69	13.00

Source: Analysis

Table 4: Total household energy consumption per month based on residential density

| No.	Type of Residential Density	Number of Households	Total Energy Consumption			
			Electricity (Kwh)	Fuel Consumption (TJ)	Cooking Fuel - LPG (TJ)	Cooking Fuel - Kerosene (TJ)
1.	High Density	29,868	7,993,432.79	53,172,347.16	16,727,468.84	432,875.24
2.	Middle Density	17,423	4,098,701.94	28,783,394.12	8,788,184.26	530,269.00
3.	Low Density	10,740	2,573,057.04	20,090,047.45	5,383,894.66	505,892.21

Source: Analysis
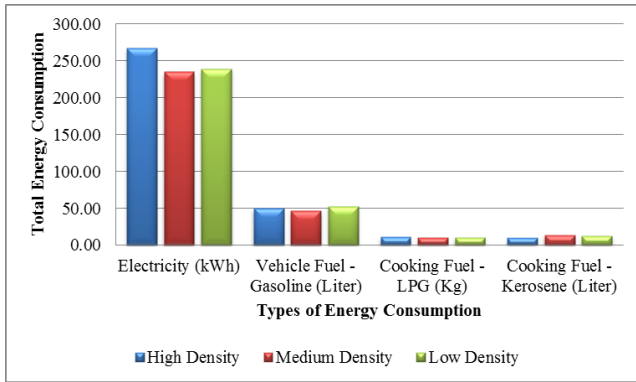
Fig 1: Comparison on Monthly Average Energy Consumption in Each Residential Density
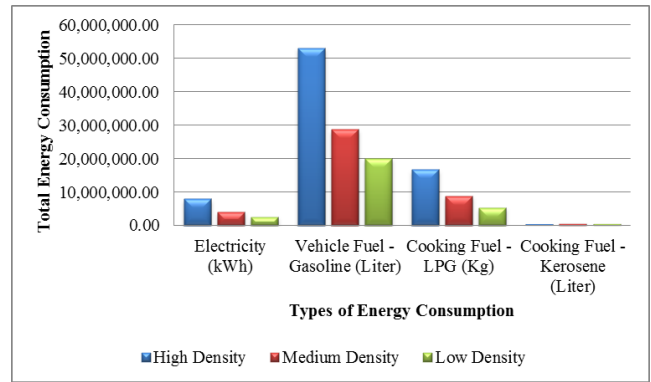

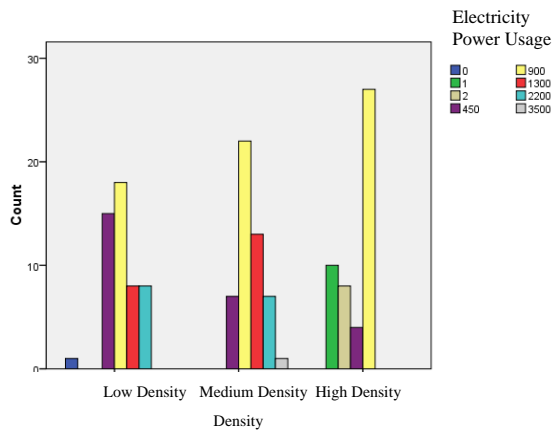**Fig 2**: Total Household Energy Consumption per Month in Each Residential Density

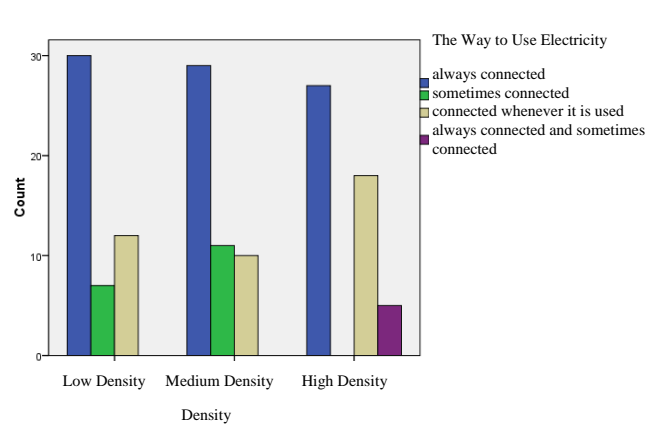**Fig 3**: Comparison on Electricity Power Use in Each Residential Density

Fig 4: Comparison on the Way to Use Electricity in Each Residential Density

3.2 Difference of Energy Use in Each Residential Density

In order to determine the difference of energy use in each residential density, the variables of residential density are used as input in cross tabulation analysis. These variables are monthly income, monthly expenses, purposes of monthly expenses, number of family members, number of car ownership, number of motorcycle ownership, building condition, land area, building area, number of floors, housing function, ventilation, use of daylight, use of electricity power, monthly electricity consumption/use, use of vehicle fuel, use of cooking fuel, time to use cooking equipment and the way to use electricity devices.

The calculation of significance value of energy consumption in each residential density by using cross tabulation can show the significance of differences of each variable. With 90% level of significance, therefore the variables with probability value less than 0.100 were considered significant to influence the household energy consumption. Table 5 showed that five variables were significantly influenced the energy consumption in each residential density. Those variables are number of car ownership, ventilation, use of electricity power, use of cooking fuel and the way to use electricity devices.

Table 5: Calculation of significance value of variables influencing energy consumption

No.	Variables	Residential Density				
		Chi Square Calculated Value	Chi Square Critical Value	df	Probability	Conclusion
1.	Monthly income	5.262	15.507	8	0.729	Not significant
2.	Monthly expenses	3.117	15.507	8	0.927	Not significant
3.	Purposes of monthly expenses	13.005	15.507	8	0.112	Not significant
4.	Number of family members	11.100	15.507	8	0.803	Not significant
5.	Number of car ownership	6.663	5.991	2	0.036	Significant
6.	Number of motorcycle ownership	11.662	18.307	10	0.308	Not significant
7.	Building condition	2.098	5.991	2	0.350	Not significant
8.	Land area	1.494	-	136	0.205	Not significant
9.	Building area	1.422	-	122	0.102	Not significant
10.	Number of floors	9.242	9.488	4	0.055	Not significant
11.	Housing function	4.296	9.487	4	0.367	Not significant
12.	Ventilation	39.449	15.507	8	0.000	Significant
13.	Use of daylight	4.412	5.991	2	0.110	Not significant
14.	Use of electricity power	69.508	23.684	14	0.000	Significant
15.	Monthly electricity consumption/use	1.013	-	88	0.157	Not significant
16.	Use of vehicle fuel	0.032	-	88	0.129	Not significant
17.	Use of cooking fuel	1.862	-	58	0.000	Significant
18.	Time to use cooking equipment	10.573	15.507	8	0.227	Not significant
19.	The way to use electricity devices	22.97	12.591	6	0.001	Significant

Source: Analysis

4. CONCLUSION

This study is intended to examine the characteristics and significance of residential density and energy consumption in Surabaya City. The findings of the study can be described below:

1. The energy consumption in each residential density varies significantly in terms of number of car ownerships, ventilation systems, electricity power usage, cooking fuel usage and the way to use the electricity.
2. The behavior of residents in high density is different with that in low density. The residents in high density always plug out the cable whenever it is not used, while residents in low density are used to plug in the cable all day.
3. The highest energy consumption for electricity in average existed in high residential density, but it did not differ that much with that in medium and low residential density.
4. Residential with high density consumed more energy significantly rather than that in medium and low density.

Although the use of kerosene had been prohibited, but the use of it in the medium residential density was still higher rather than that in high and medium density.

5. ACKNOWLEDGEMENT

6. REFERENCES

[1] Anderson, W.P., P.S. Kanaroglou and E.J. Miller, Urban form, energy and the environment: a review of issues, evidence and policy. Urban Studies 33(1), 7-35, 1996.
[2] Ewing R, and Fang Rong, Housing Policy Debate, Volume 19, Issue 1, Metropolitan Institute at Virginia Tech, 2008.
[3] Miron, John R., Housing Demand, Coping Strategy, and Selection Bias. Growth and Change, 35(2):220–61, 2004.
[4] Indonesia, Handbook of Energy and Economic Statistics of Indonesia, Jakarta: Ministry of Energy and Mineral Resources of Indonesia, 2011.
[5] Kementrian Negara Lingkungan Hidup, Emisi Gas Rumah Kaca Dalam Angka, Jakarta, 2009.
[6] JETRO, Market Investment Attraction – Indonesia, Japan: Japan External Trade Organization (JETRO), 2011.

[7] Yunus, H. S., Manajemen Kota Perspektif Spasial, Yogyakarta: Pustaka Pelajar, 2005.

[8] Surabaya City Government, Preliminary Identification Report of Surabaya Spatial Plan, 2009.

[9] Adisasmita, R., Pembangunan Kawasan dan Tata Ruang, Yogyakarta: Graha Ilmu, 2010.

[10] Setiawan, R.P., Ema Umilia, Ketut Dewi Martha Erli H., 2013, The Correlation between Residential Density and Greenhouse Gas Emissions in Surabaya City, Proceedings of International Conference on Regional Development, UNDIP, Semarang, 2013.