Post occupancy evaluation of energy-efficient behavior in informal housing of high density area

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Abstract. The concept of energy-efficient building emphasizes the critical of efficiency in the use of water, electrical energy, and building materials, beginning with design, construction, to the maintenance of the building in the future. This study was conducted to observe the behavior of Energy Saving of the residents in performing everyday activities in the building. The observed variables are the consumption of natural resources (energy, material, water, and land) and the emissions of air, water, and land related to the environment and health. This research is a descriptive qualitative research with the method of data collection is the distribution of questionnaires and observation. The method of analyzing data is posted occupancy evaluation undertaken to obtain patterns of community-based behavior in urban areas. The informal high-density housing area is a typology of population settlements that found in many big cities in Indonesia. This community represents various community groups regarding occupation, education, income, and race. The results of the study concluded that there are five components of energy-saving behavioral formers in housing namely: residential building components, environmental components in occupancy, external occupancy components, components of social activities and elements of business

1. Introduction
The concept of energy saving house emphasize in the increase in the efficiency in water, electricity and material usage started from the design to building maintenance in the future. Energy conservation behavior significantly affects the plan, the construction and the maintenance of the energy saving building itself. [1]. The condition of the nearby environment also affects the energy consumption of a house such as a tree position, building position and orientation and also building density.[2]. The highly populated urban area is the typological landscape of resident environment that can found frequently. Another aspect that affects energy saving is living lifestyle. Research by [3] suggests that living lifestyle can be evaluated to obtain energy consumption and can be used to predict future energy use. Energy saving lifestyle is important to the researcher to realize the concept of energy saving house. The aim of the study is to observe the energy conservation behavior in a highly populated residential area.

Energy-efficient house
Energy-efficient houses utilize many opening in its design to maximize air circulation and natural light and also minimize the usage of the lamp and air conditioning during the daytime. The plan also limits
building area, utilizes simple design, utilizes room flow, uses high-quality material efficiently, uses eco-friendly material and utilizes energy saving lifestyles such as alternative energy utilization such as the wind and natural light. The roof of the building can develop into roof garden and solar panel roof which in return lowers the ambient air temperature, lower pollution and increase green open spaces [4].

Some aspects needed to be considered in the concept of energy saving house are [5]:
1. Efficient and economical consumption of resources (energy, material, water and land space).
2. Good emission into the air, water, and land associated with its impact towards the environment and health.

Environmental component around the building consists of laying of the constructing and planning the activity space. Laying of the building will be affected by the climates such as sun light, rainfall, and the wind. Planning activity area will be affected by activity types, furniture layout, room requirements and residents’ lifestyle.

Sun light can function as natural light during daytime inside the building. It can also be utilized to lower the humidity in the building. Rainfall, especially heavy rain with high winds, can cause water leaks on the openings of the building. Using big tilted roof will help prevent water leak in the building.

Building materials susceptible to rot and mold should equip with open rain channels located below the ceiling to drain the rainfall into infiltration wells and ditches on the side of the road. Proper ventilation should be in the same direction as the wind direction. Wind will help cool the air and circulates the air to the environment.

Energy-efficient behavior in residential area

Living lifestyle should follow energy saving behavior. Theories of energy conservation behaviors in living have researched by many researchers. As a basic theory, energy conservation behavior in a residential area was said to be affected by three aspects such as (1) external influence (2) community impact and (3) personal influence. [6]. External influence is the influence of the condition of the environment nearby the housing area. Community influence is the influence of the lifestyle of the community nearby the housing area. Individual lifestyle is the influence of the person residing the housing area.

Some activities of the residents can categorize into general activities (rest, working, and hygienic activities) and specific activities (gardening, businesses, and hobby).

Each activity occupies different spaces inside the house each with different specification and requirements that support those activities. [7] categorized areas inside the home in regards to energy usage into three clusters: Cluster 1 which is kitchen area, Cluster 2 which is entertainment area and Cluster 3 which is another aspect. The results obtained through analysis suggest that highest energy usage occurs in group 1 followed by group 2 and group 3. The research concluded that understanding energy consumption in residential housing would be more appropriate using socio practical theory approach which is accurate theory in behavior and habit, relationship between humans and materials, competence and activities significance.

Based on activity types in the family, each space provided according to the number of household member, furniture or tools used and circulation or activities traffic. Two activities can function in the same space in different times, and space has the similar characteristic. Time management in space and tool usage can also use as a strategy to save energy.[8]

Using environmental friendly kitchen equipment as opposed to regular kitchen equipment can help reduce energy usage. Replacing conventional oven with electric oven helps minimize the emission of greenhouse gases from the house to the environment. A good refrigerator helps balance energy usage with temperature control. These examples help sustainable living by reducing energy consumption. In designing the interior of the kitchen, using energy saving appliances can contribute to reducing the energy bill.
Kitchen ventilation settings. Kitchen with good ventilation will use less energy and lighting during daytime. Fresh air from windows and ventilation helps reduce harmful gases and mold.

Figure 1. Research Schematic [9]

Energy-efficient concept
In Indonesia, primary energy (kerosene) is consumed mainly for cooking. However, consumption of electrical power increased lately (around 7% increase) with the assumption that 50% of the total power used in residential sector. Residential area significantly affects electricity consumption specifically for lighting, household appliances, and air conditioning. As a developing country, Indonesia will increase the quality of life of its citizens. As such, electricity consumption in the home used for life convenience purposes such as air conditioning system and lighting systems [10]. For cooking purposes, LPG or coal briquettes will replace oil usage. In regards to energy saving concepts, there are parameters to be considered such as:
1. Thermal convenience is used to control the absorption of solar energy needed for a household. Buildings in the hot climate in Indonesia need to be able to block the sun heat for cooling purposes.
2. Visual convenience is used to control sunlight absorption for natural lighting purposes.
3. Passive environment control is the utilization of natural energy optimally without the usage of high technology tools. Thermal and visual convenience can control by utilizing the potential of climate monitored by the elements of the building such as roofs, wall, floor, etc.
4. Active environment control is used to monitor the environment using tools or appliance to achieve thermal and visual convenience.
5. Hybrid environment control is the combination of passive and active environmental control which means some parts uses passive environment control while other parts used active environment control.

2. Method
This research is a descriptive qualitative research. Primary data collection acquired through interviews and observation. This study examined the behavior and perception of housing residents related to
energy saving lifestyle. The location of the research chosen was in Kecamatan Medan, which was one of most populated districts in Medan City. Twenty-five houses used as research sample however only ten households were willing to be respondents to research on post-residency evaluation as a method to analyze data of residents’ behavior pattern after five years minimum of occupancy.

Figure 2. Research Location at Jl. Wakaf Medan Area District

3. Results and Discussion

Use of Appliances

The power consumption of each respondent can consider as fair, ranging between 300-600VA per month with the total power supply of 900 VA for each house except Respondent 7 (R7). The power consumption of Respondent 7 considered high which is almost equal to the power provided to the house which is 900VA.

This high power consumption was caused by factors such as:

- A large number of residents, which was ten persons. (two family households living in the same house).
- Water supplied from underground wells as opposed to water companies. As such, to provide water for the house water pumps were used which then increase power consumption.
- Wasteful energy consumption. For examples, the usage of electronic appliances such as TV, laptop/computer, and fan used simultaneously for extended periods of time (until early morning).

Family characteristic from economic aspects will affect the energy consumption in a household. However, the knowledge on energy saving concept in a house is related to the education level of the household. [11]

The result of the interview from all ten respondents suggested that there was no significant effort in reducing energy consumption. Furthermore, no respondents were using alternative energy as power sources. All respondents still relied on conventional energy supplied by the government.
Control and interaction with environment

All respondents’ houses were north-south oriented with slanted roofs. However, some of the roofs were not full enough. Natural ventilation was adequately applied but not fully optimized because of houses attached to one another. Building orientation was North-South oriented. (Figure 3)

Figure 3. North-South oriented house

Data on the health and convenience condition listed on (Table 1). Eight aspects reviewed with ratings of Good (G), Average (A) and Bad (B)

| RESPONDENT | GOOD | AVERAGE | POOR |
|------------|------|---------|------|
| R1         | _    | Air conditioning, Garden condition, Water puddle, Vegetation, Roof condition, House cleanliness | Lighting, Temperature and Humidity |
| R2         | _    | Lighting, Air conditioning, Temperature and humidity, Garden condition, Water puddles, Vegetation, Roof condition, House cleanliness | _ |
| R3         | Lighting, Garden condition, Water puddle, Vegetation, Roof condition, House cleanliness | Air conditioning, Temperature and humidity | _ |
| R4         | _    | Lighting, Air conditioning, Temperature and humidity, Vegetation, House cleanliness | Garden condition, Water puddles, Roof condition |
| R5         | House cleanliness | Lighting, Garden condition, Water puddles, Roof condition | Air conditioning, Temperature and humidity, Vegetation |
| R6         | Lighting, Air conditioning, Temperature and humidity, Water puddles, Roof condition, House cleanliness | Garden condition, Vegetation | _ |
| R7         | _    | Lighting, Air conditioning, | Garden condition, Roof |
According to the table above, no house has all good rating; all of them were mostly average or bad. Common problems happen in lighting, air conditioning, temperature and humidity, and cleanliness (inside and outside of the house). The cause of these challenges was:

The position of the houses was attached to one another. As such, openings such as doors, windows, and ventilations located in front of the houses only. The possibility of cross ventilation was small, and the size of the openings was little as well (in comparison with room size).

Household characteristic
There were no problems in regards to income or outcome of respondents. All respondents were capable of providing daily needs. In fact, Respondent 4 (R4) has no job (livelihood supported by the children), and R4 still feels convenient. To sustain economic activities, each respondent cannot depend on the primary source of income but also needs another source of income. There were three out of ten respondents that have alternative source of income. Respondent 1 has beauty salon with the turnover of Rp 2.000.000/month. Respondent 2 has home contracting business with the turnover of Rp7.500.000/month. Respondent 8 has gunny craft business with the turnover of Rp1.000.000/month.

Perception and Motivation
The only one that has the problem was Respondent 7 (R7). Energy saving concept (openings, space arrangement, alternative energy, etc.) will have little impact because the root of the problem is in the behavior pattern. The primary cause of high energy consumption is the simultaneous usage of 2-3 laptops/computers over the extended period (often until early morning). During that time fans and light were turned on as well and never turned off again because of oversleeping. This behavior occurred due to the job demand that cannot avoid. Hence the concept of energy saving by reducing the usage of the electric appliance cannot be applied. The respondent’s perception in energy conservation will affect the respondent behavior toward energy efficiency. [1] Information on energy saving was still inadequate that motivation toward energy conservation was small as well. Apart from the sanitation, garbage also became a problem for many respondents such as R1, R4, R7, and R10. The problem occurred because there was no garbage dump in front of the house. Inadequate waste management will likely create floods in the future.

4. Conclusion
Perception of energy efficiency was still inadequate. Information on energy saving behavior was less understood because of lack of information and socialization in energy efficiency. Control and interaction toward the environment were still not prioritized because of other livelihood needs.
Managing energy usage has been done by several households although the motivation was not for reducing energy consumption but for reducing costs. Usage of environmentally friendly material was still scarce because of the expense of those materials were still high.

5. References

[1] Kao T F and Tu Y C 2015 Effect of Green Consumption Values on behavior : The Influence of Consumption Attitude International Journal of Arts and Sciences 8(8) 119-130

[2] Nelson C, McHale M R and Peterson M 2012 Influences of lanscape and lifestyle on home energy consumption Urban Ecosystem 15 773-793

[3] Gajowniczek K and Zabkowski T 2017 Electricity forecasting on the individual household level enhanced based on activity patterns PLoS ONE 12(4) e0174098

[4] Nikoei M, Falamaki M M and Masoudi A 2014 Saving Energy in Building through Local Architecture Principles European Journal of Natural and Social Sciences 3(4) 301-308

[5] Yudelson J 2009 Green Building through integrated design 1st edition New York: Mc Graw Hill Company

[6] Mayne R, Darby S and Jo H 2012 A literature Review for the EVALOC Project. Individual and Social Influences on Energy Use Evaluating Low Carbon Communities 1-51

[7] Thomas E G, Walker I, Verplanken B and Shaddick G 2016 Householders' Mental Models of domestic energy consumption using a Sort-End-Cluster Method to identify Shared Concept of Appliance Similarity PLoS ONE 11(7) e0158949

[8] Buys L 2015 A Framework for understanding and generating Integrated Solutions for Residential Peak Energy Demand PLoS ONE 10(3) e0121195.

[9] Santin O G 2013 Occupant behavior in energy efficient dwellings : evidents of a rebound effect. Journal Housing and the Build Environment 28 311-327

[10] Nuryanti and Herdinie S S 2007 Analisis karakteristik konsumsi energi pada sektor rumah tangga di Indonesia Yogyakarta Seminar Nasional III SDM Teknologi Nuklir

[11] Jovanovic R, Bousselham A and Bayram I S 2016 Residential Demand Response Scheduling with Consideration of consumer Preferences Applied Sciences 6(16) 1-14