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Domestic Energy Practice in Vertical Housing

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ABSTRACT

To achieve a certain level of comfort, the main concern regarding thermal comfort in Indonesia is not about heating up the space, but rather cooling it down. In domestic environment, an active cooling activity involves energy consumption and it varies amongst households. This paper is to examine a desired level of comfort and the energy consumption in achieving the comfort level in a vertical housing for middle-low in Kemayoran, Jakarta. Whilst energy consumption in domestic environment is determined by physical factors, such as electrical appliances and spatial setting, it is also influenced by non-physical factors, such as norms and practices of the energy user. The study was conducted through field observation, mapping and structured interviews, as based for qualitative analysis. As result, various strategies in the practice are developed within the limited space by the energy user to achieve their comfort, despite the constricted supply of energy. These energy practices can be insights to a sustainable vertical housing design, in terms of achieving comfort and energy efficiency in the domestic environment.

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Keywords: comfort, energy consumption, energy practice, vertical housing

1. Introduction

Domestic energy consumption is a function of the structure and intensity of energy use in home, which depends on the dynamic relation between the energy user, the physical setting that includes domestic unit and the context aspects [1, 2, 3]. Understanding energy related behavior, i.e. energy consumption, can inform policy-making in developing effective strategies and priorities, to improve the energy performance and to reduce energy cost [4, 5, 6]. Although understanding energy consumption can be a useful basis for scenario building, its contribution as possibility to improve comfort in building design is rarely discussed. Meanwhile human comfort and wellbeing play as an important role in the matter.

Energy related behavior, i.e. energy consumption, is a complex concept to be understood and shaped by many factors. To understand the concept, a culture-based approach is necessary and therefore a modell is developed to explain the concept [2]. The modell categorizes the factors into three categories, namely material culture, cognitive norms, and energy practices. [2].

The physical setting has impact on the thermal and energy performance of the house and therefore determines the energy consumption. Floor area, age of building, type of construction, ventilation, lighting, source of energy, insulation and infiltration, heating or cooling system, household appliances, are considered as material culture. Not to mention the location, orientation of the building and climate of the residence, and technology, that act as the context [1, 2]. Cognitive norms deal mainly with norms, beliefs and understanding of the energy user, which is strongly influenced

by socio-cultur, history, educational background, ideology, income, and energy consciousness. Meanwhile the energy practices is strongly related to the activities and process, which can be observed through habit, lifestyle, and energy related practice, i.e. usage duration, frequency, purchase, maintenance, etc. Energy practices depend on the size of the domestic or household and signify needs of basics, comfort, or sanitation [1, 2]. Both cognitive norms and energy practices depends heavily on the energy user and functions as modifiers. As a consequence based on the modell, energy consumption of two domestics in similar physical setting can differ from each other due to the characteristics of energy user.

On the other hand, comfort itself is not perceived individually, but it is also learned. Through cognitive process, comfort is shaped by social and cultural values, norms, needs and motives influence these conditions, whether as individual or member of social groups [7]. Comfort (i.e. thermal) is not as static absolute need, but something that has developed over time, within different sociotechnical settings and developments [8]. This implies that comfort level can be considered as one of cognitive norms. Based on literatur reviews several determining or modufying factors are positioned in the energy culture concept (Table1).

Meanwhile the domestic environ is not always in favor for the user. Due to the land scarcity and rising land price in big city like Jakarta, the middle low class has only limited options for living, either utilizing affordable landed houses in oustkirts of Jakarta, living in a densely urban kampong, or living in vertical housing built by the government. The housing is designed to follow the national standard for vertical housing within constricted budget to meet the affordability aspect. As a result, the space and the facilities conform the basic function, building standard, code and regulation. It is habitable, but often neglects the uniqueness of the socio-cultural aspect of the inhabitants.

Based on the Indonesian national standard for stacked housing for middle and low-income community, the dwelling unit cannot exceed 45 sqm and the construction price per sqm cannot exceed the standard of the public/governmental high-rise building (class C – the lowest cost) [9]. The basic requirements: provision a certain quality of health, security, thermal condition, and clean air are to be met and the authority has set the prototype of the vertical housing to be constructed. If minor innovations from designers are possible to be developed in the design, certain design criteria regarding tropical climate like cross ventilation system is mandatory. The structure or construction and infrastructure in every unit are typical.

Typicallity is also applied for energy/ electricity and water supply, which was only for primary need at the early time of occupation. These are most likely inadequate for present time. For example, the smallest unit 21 sqm was planned to be supplied with 450 VA, whereas the 36 sqm type provided with 900 VA. The provision of electrical socket, switch, fitting, faucet, plumbing and the drain is at minimum.

Those who are now living in vertical housing can be included to generation who had experience living in landed house. As they moved to vertical housing, they may encounter difficulties in adjusting to their new living condition due to the different arrangement of space and facilities provided. Not only have they had to adapt to the small living space, but also the limited power and water supply. Another limitation is that the social activity in the neighborhood. They use the shared access, roads or alleys between living compartment, common facility, and every possible corner for gathering, which is very liquid and horizontal.

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Tabel 1. Categories in Energy Culture

Norms [Believe, understanding]	**Material Culture [Building form, setting, technology]**	**Energy Practice [activitie processes]**
Government's policy, rules	Physical – type, envelope, size/area, layout, age	Type of activity – cooling, lighting, gas, electrical appliance
Value or ideology	Location – weather, sun path shade, greeneries	Usage – duration power, frequency, purchase systen payment method, maintena
Social- Culture	Climate – temperature, rainfal humidity, sun intensity, air qu	Endogenous & exogenous character of energy user
History	Building Condition	
Information	Appliances – price, size, numb energy efficiency rate	
Control – knowledge & awar		

Source: Literature Review Analysis, 2014

Located in the tropical zone, Jakarta has a tropical climate with hot temperature and high humidity (Jakarta's annual average temperature 25-380C and 65-85% humidity) [10]. The main concern regarding thermal comfort is not heating up the space, but rather cooling it down. Provision of hot water is not an issue, since most of washing, cleaning and cooking activities do not require hot water as in countries in sub tropical climate. Daylight occurs almost 12 hours throughout the years and it helps to lessen the use of the artificial lighting. The mechanism related to thermal comfort applied in the design of the tropical house is usually by providing ample openings and traditional cross ventilation. But these may not always be possible in an extreme condition such as for high rise building, where the wind velocity and pressure are higher or pollution occurs greatly.

The purpose of this paper is to examine various energy practices in limited domestic environment with a certain level of comfort as the norm. This can be used as evaluation and insights of the vertical housing designs to improved energy culture. The energy culture modell [2] will be used as the basis for an explanation of energy related behavior in limited physical setting and how strategies are developed in the setting to get, at least, corporeal comfort. This paper begins with an overview of vertical housing, characteristics of the inhabitants, and their behavior and habits that explain their cognitive norms, energy practice, as well the material culture.

There are two types of vertical housing in Kemayoran, rusunami (rumah susun sederhana milik – to be owned) and rusunawa (rumah susun sederhana sewa – rented only). Both types are intended for low income group. The units in the Apron block consists of 6 blocks consist of 21 sqm unit and 2 blocks of 36 sqm unit. Each block has 5 storeys (Figure 2).

(Source: http://appejawa.navperencanaan.com /peta/viewmap?prov_code=jakarta, 2016)
Figure 1. Location Kemayoran, Central Jakarta, Indonesia

Based on the construction of the vertical housing in Kemayoran, the Apron Blocks consists of two types of unit based on their floor area: 21 sqm and 36 sqm (Fig 3 and 4). The typical 21 sqm unit consists of one room which serves basic needs of the resident for sleeping and resting with possible area for cooking, apart from the bathroom and the balcony.

Meanwhile, the 36 sqm unit consists of three rooms: two bedrooms and a common/ living room, a service area for kitchen and bathroom, and a balcony as well.

No temporary divider or partition in the room with largest size is found.

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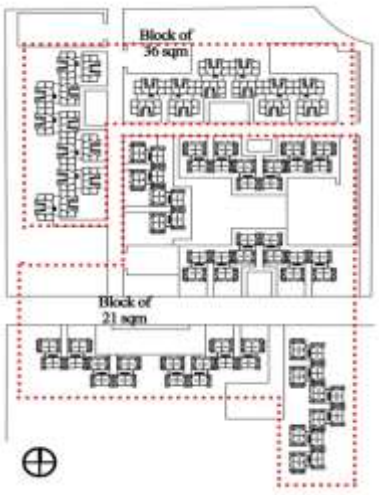
(Source: Google Maps, retrieved 2015)
Figure 2. Blocks of Vertical Housing Kemayoran Central Jakarta, Indonesia

All the unit was planned to have access to the shared circulation in the middle of the building and outdoor space through door to the balcony and windows, which actually allow cross ventilation and optimum natural day lighting in the unit to happen. Eighty percent of the observed units have north-south orientation. The construction materials are concrete for the structure, masonry with plaster for wall, concrete ceiling or gypsum ceiling for the rooftop units with average ceiling height 2.7 m, ceramic for floor, and wooden frame for doors (panel) and glass for louver and windows.



(Source: Field Survey, 2013)
Figure 3. Arrangement of Units, Vertical Housing Kemayoran

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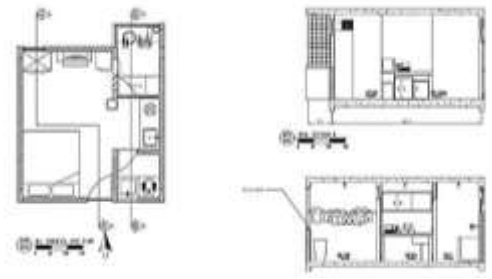
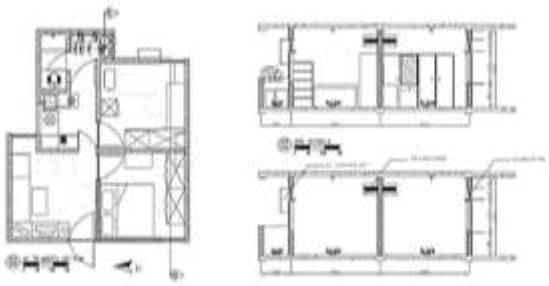


(Source: Field Survey, 2013)
Figure 4. Typical Unit 21 sqm (Floor Plan and Sections)



(Source: Field Survey, 2013)
Figure 5. Typical Unit 36 sqm (Floor Plan and Sections)

2. Methods

This paper is based on study conducted in vertical housing in Kemayoran, which situated on Apron Street. Forty-seven units were taken randomly as sample in the study, which consist of 38 unit of type 21 sqm and 9 units of 36 sqm, to represent a range of the units.

The study itself is an attempt to understand the the comfort level in relation to the condition in vertical housing. Observation and questioners were conducted. As research instrument, the structured questioner identifies the residents' perception of the thermal condition in their units. Strategies or certain behavior of the residents related to thermal condition were scrutinized. The units were also observed and mapped to identify (a) number of electronic appliances in the units and the frequency and duration of using - to give an overview of the energy consumption in each unit and (b) how residents organized their interior to achieve their maximum acceptable comfort, corporally as well as socially of the unit, which includes units's modification.

The data collected from the questioner is analyzed statistically using Chi-Square-Test and Pearson Coefficient to find (in) dependency and the correlation between the cognitive norms, energy practices, and the material cultural factors. Another analysis is conducted by using the mapping results to see the consequences of the strategies practiced by the residents. The focus of this study is primarily to identify the strategies applied related to socio cultural aspects in their everyday practice and the energy consumption to achieve comfort within the available space and construction. By practicing good energy culture, a reduction of energy consumption can be expected.

3. Result and Discussion

The characteristics of the households participated in the questioner and observations are mainly from the income groups of IDR 1-3 million (44.7%) and group of IDR 3-5 million (25.5%) (n=47 households). Each unit in this vertical housing is occupied only by household and almost 60% of the households are represented by housewives and pensioners. From the survey, 29.8% of the surveyed units consist of 4 members and 25.5% of 5 members. Based on the survey, the 21 sqm unit can be utilized to cater until 6 persons, where the household is young adult family with children.

Having experienced living in landed house and in a tightly packed housing environment, some of the residents have difficulties in undergoing the transformation. Based on the responses of survey, the units with an average 3-4 inhabitants/unit are considered too small and/or noisy by 10% of the respondents. Despite these conditions, this living option is still considered better compared to the previous living

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experienced on landed house and favorable due to the economical reason, safety, strategic location, facility, and can still cater the social need through a good community bonding.

All the unit was planned to have access to the shared circulation in the middle of the building and outdoor space through door to the balcony and windows, which actually allow cross ventilation and optimum natural day lighting in the unit to happen. Eighty percent of the observed units have north-south orientation. The construction materials are concrete for the structure, masonry with plaster for wall, concrete ceiling or gypsum ceiling for the rooftop units with average ceiling height 2.7 m, ceramic for floor, and wooden frame for doors (panel) and glass for louver and windows.

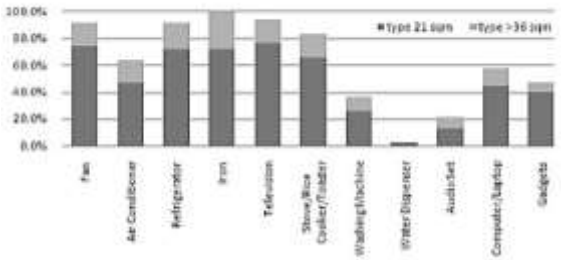


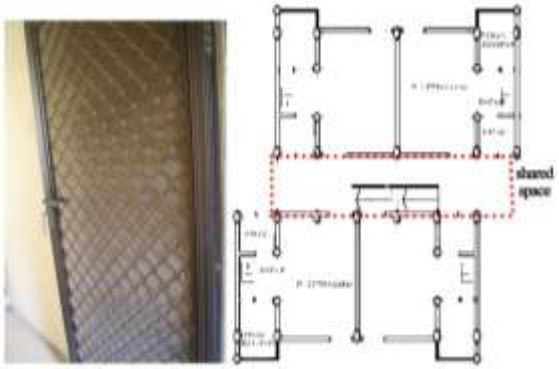
Figure 6. Electrical Household Appliances Utilized by the Inhabitants

To support their daily needs, they equipped their units with fan and/or air conditioner, refrigerator, television, stove/rice cooker, ironing equipment, which can be concluded as basic electrical appliances for three functions in their dwelling - basic domestic activities, and supporting comfort, thermally and socially (Figure 6). This number and type of appliances utilized in a household are in accordance to the lifestyle of the inhabitants. This also implies the level of comfort and the value in health expected from the inhabitants [12].

Physical comfort, i.e. thermal comfort in the unit is important for the inhabitants. More than 78.5% of the respondents feel physically comfortable and 73% of them relate it to the thermal condition in the unit, which was described as cool or not warm (i.e. 55% of the whole residents). In general, round 60% of the respondents find their units cool, which expressed more often from the 36 sqm units compared to the 21 sqm units.

The assessment for the 21 sqm units basically focused on the living/bedroom as the main room in the unit. Ranging from scale of 0 for very warm until 5 for very cool, 34% the residents in the smaller units gave the score 3 (relative cool) and 32% considered as cold/very cold for their living/bedroom. The rest assessed their room as hot or warm.

Compared to the condition in the bigger units, 44% the residents find the living room as relative cool (score 3) and 32% as cold/very cold (score 4 and 5) and only 11% considered the room as hot-warm (score 0, 1 and 2). Around 11% regard their living room is warmer than their bedrooms, which actually related to the usage of air conditioner and electronic fan.



(Source: Field Survey, 2013)
Figure 7. Non-electronic related Strategies in Vertical Housing in Kemayoran: The Front Door and Possible Shared Space

Practice employed by the inhabitants to achieve thermal comfort in the unit is by opening the windows and door in the units to allow the fresh air entering the unit, going outside the unit and occupying cool spot in the building, or both. Around 58% of the whole respondents open the windows and 25% going outside the unit. More inhabitants in the smaller unit open the window

and it is more frequent rather than the bigger unit. Noise and the relationship with the neighbor, which is considered as "interfering" of the single households' privacy in present time, are two of many reasons for not doing it. The residents, who favor to open the door, usually equipped their door with another layer of door from aluminum door, which allows the air to flow in the unit (Figure 7).

Another practice to achieve the comfortable condition in the unit is by utilizing electronic appliances, which is more prominently found in this study. More than 27.5% of the households use electrical fan or exhaust fan, 21.3% utilize air conditioner, and 36.2% use both appliances. These answers are then to be categorized into two groups, based on their unit floor area. As mentioned before, aside from a bathroom and a balcony, the 21 sqm unit only has one room for sleeping, resting, as well as cooking without partition, with possibility to have averagely same perceived temperature condition in that room. Meanwhile the 36 sqm or more has minimal two bedrooms, a living room, a small kitchen, a bathroom and a balcony, which indicates significant variation of perceived thermal condition in the unit and the comfort, for example in the living room and the bedroom. These resulted in variation of the thermal condition perceived by the residents as followed.

Their expressions of thermal comfort are however in contrast to the use of electrical appliances like fan or air conditioner. They, who considered their room as cool or very cool, use mostly only electrical fan, although the units are occupied by more than 4 people. As comparison, the other units, which are considered relative cool, mostly utilized air conditioner and electrical fan at the same time. In this type, all the units apply air conditioner and being supported with electronic fan. The physical setting is considered cool or very cool after the usage of the cooling appliances and to achieve comfort. That result can be interpreted the physical setting is actually not a comfortable area, cooling system is needed.

Moreover, the fact that no unit is found without electronic fan or air conditioner shows that those appliances have an influential role in the thermal comfort in vertical housing and the usage of those appliances is the most chosen strategy in achieving thermal comfort. They turn on the air conditioner and/or electronic fan at least 3 hours per day and more than half of the owners of those appliances turn them on for more than 8 hours. This indicates high dependency on the appliance and that the thermal condition in the unit is actually warmer than the resident's standard condition of being comfort, despite more than half of the whole respondents feel thermally comfortable. The dependency also means that the comfort becomes the trigger for using electrical appliances and consequently more energy consumption, especially in the bigger units.

That level of comfort can be considered as constructed, in which the residents learn the thermal comfort should be in certain degrees of temperature and to produce these temperature, it can be achieved effectively by using air conditioner. Not only that, the use of air conditioner means more energy cost, and therefore can be used as the symbol of the welfare of household socially [7]. The fact that the Indonesia's GDP per capita arises each year and the price of the electronic gets more affordable gives bigger chance for the people to buy air conditioner [2]. Due to the increasing amount of the electric consumption, it can be seen that the middle low-income groups, as the majority residents in vertical housing Kemayoran, have more capability to afford higher energy consumptive life, to serve various activities ranging from domestic basic

needs, businesses, to recreate or entertainment-purposed activities.

These electronic appliances preferences have consequences on the indoor quality. By using air conditioner, they realized that they have to keep the cooled air as possible as they can inside the unit and not leaking outside. In order to do that, the louver, clerestory or other opening above the door or window are covered with leak proof material, such as paper, fiberglass, plastics, or plywood. By doing that, the noise from outside the unit does not infiltrate (advantage), but the cross ventilation does not work anymore and the room is darker (disadvantage).

The unit is not furnished as the residents rent the unit; they bring their own furniture and arrange it according their need. The most common furniture in the bedroom is bed, drawer and clothing cabinet; shelves and small table for the common or living room. This furniture is usually in big size, not especially design for a compact living unit, which most likely brought from the previous dwelling. Interesting to be found, is that each household actually has a big number of objects that have to be catered in storage. Due to the limited space the arrangement of the furniture, these storages are set nearby windows and the laundry, also affects on the indoor lighting quality (Figure 8) – therefore the duration of using lamps increases and thus the electricity consumption.

The inhabitants arrange the home objects refers to the structure in the unit, such as closures openings, electrical socket, faucet, plumbing and the drain. These aspects influence the residents' behavior and presumably the strategies in achieving their well being in a limited situation, inside the units. The new installation of power socket is seldom, while cables and the use of extension are more preffered due to the limited placement. This also affects the healthy and safety condition in the unit, since the arrangements paralyze some function of the construction and even weaken the performance of the construction, for example fire escape.

(Source: Field Survey, 2013)
Figure 8. Furniture Arrangement and Consealment of the Openings

Since the unit was designed without space cooling or heating system, there is no special insulation installed. The electricity is supplied mainly by the PLN and each unit is equipped with one socket, switch and lamp in every room, including kitchen. Some of building blocks are also equipped themselves with generator set, in case problem with the supply from PLN occurs. Therefore, the arrangement of the electronic appliances, such as

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refrigerator, television set, stove/ rice cooker in the unit depends of the socket in the living room and/or bedroom (dry area). Limited space caused the placement of the refrigerator in the living room instead of in the cooking area (intended as kitchen in the unit). New arrangement is created. The cooking area and the utensils are being moved out to the balcony.

However, this arrangement does not apply for the air conditioner: new installed extra socket is provided especially for the use. The air conditioner indoor unit is placed on the wall, which has connection to the nearest outdoor space. Common to be seen in the units bigger than 36 sqm, the air conditioner is being placed in the living room or between the two bedrooms using hole in the wall.

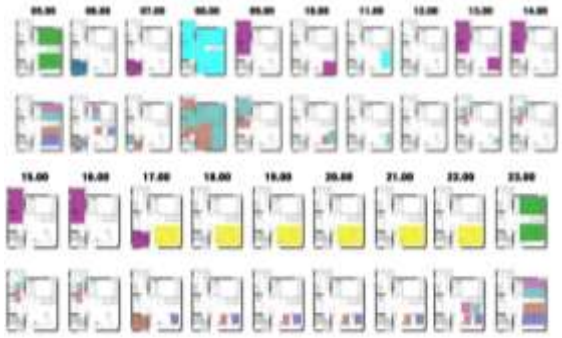
As for cooking/stove, they use mainly portable LPG container (liquefied petroleum gas). General artificial lighting in the units are ceiling mounted using CFL (compact fluorescent light) in each room, meanwhile table lamp, other ambient lighting or even incandescent bulb were very rarely seen. Water supply in the building depends on the PDAM (local water supplier) and used only in form of cold water. The installation of hot water system for washing or bathing was not found in the vertical unit. The culture of using hot water for washing or bathing as hygienic/sanitation reason is seldom in Indonesian domestic, especially in the low-income group. If hot water for bathing is needed, they cook the water using the stove. Energy consumption occurs also in another form of energy but in a controllable manner due the purchase system.

(Source: Field Survey, 2013)
Figure 9. Poor Lit Areas inside Unit

The usage of tumbler for drying clothes was not found as well, the resident takes advantages of the abundance of light and fresh air and uses the balcony for the need, although this activity has consequences for the lighting quality of the unit (Figure 9, Figure 10). This physical setting, which is benefited from the climate, allows such practice, even though implications arise and encourage further energy consumption.

Another practice of energy saving that can be seen is the usage of outdoor environment to get thermal comfort. There are courtyards between the building blocks and common facilities on the ground level used for the social activities in the neighborhood. The inhabitants reduce spending time inside unit by doing outside activities, such as working and social activities, especially in day time.

(Source: Field Survey, 2013)
Figure 10. Furniture Arrangement and Consealment of t Openings



(Source: Field Survey, 2013)
Figure 11. Pattern of Activity in the Unit in 24 Hours Time

The electronic household appliances contribute their energy consumption and the cost spent. Monthly 31.6 % of the 21 sqm unit and 44.4% of the more than 36 sqm unit households pay IDR 200,000 - 300,000 for electrical bill. This is relevant due to the basic electronic appliances found in the units, which shows similar pattern, whether 21 sqm or 36 sqm: electrical fan, refrigerator (average size of 160 liter), television, ironing set, and rice cooker; even though differs in number, which implies that these electronic appliances are elementary for their daily activities (Figure 6).

With the usage of electricity for these appliances nowadays, the intended electricity supply (450 VA and 900 VA) cannot support the need of the household any longer. For this reason, the households are raising their supply power minimum to 900 VA and 1300 VA for them, who utilized air conditioner. The prower shortage becomes a setting or determinant material culture. Although similar usage of electronic appliances occurs, the number and duration of use, which is actually much related to the residents' practice, play important role in the energy consumption as the modifying factors.

Statistically, there is dependency and strong correlation between the electrical consumption (using electrical bills as indicator) and the household's income (Chi2=47.03, df=9.49, Ckorr=1.00), as well as the size of their unit (Chi2=138.95, df=21.03, Ckorr=0.99). Smaller unit households tend to pay lesser than the bigger unit's (Fig.12) and lower income groups pay lesser than the higher income groups (Fig.13), although it is difficult to prove the dependency between the size of the units and the household's income (Chi2=4.94, df=12.59). The monthly cost for electricity used as part of controlling their energy consumption.

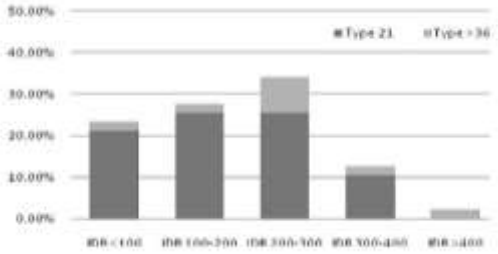


Figure 12. Monthly Electrical Bill based on Uni Types

Based on Ministerial for Energy and Mineral Resources Regulation No 30/2012, the basic energy price for household in Indonesia is IDR 415 and IDR 605 per kWh for respectively the supply circuit of residential within 450 VA and 900 VA. As for residential with more than 1300 VA, the basic price is at least IDR 833 per kWh. The domestic energy consumption in Indonesia is 11% of the national consumption [11], where PLN (national electricity company) acts as the

main distributor. According to the statistics, 98.65% of the households in Jakarta use electrical supply from PLN [9].

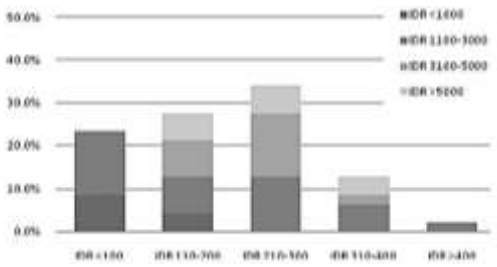


Figure 13. Monthly Electrical Bill based on Income/Unit

While the smallest unit 21 sqm was planned to be supplied with 450 VA and the 36 sqm type provided with 900 VA, it turns out that the inhabitants decided to raise their power supply option to 1300 VA maximum. New purchase system introduced by the PLN, from post payment to pre-payment with token, is not considered familiar. They consciously maintain their energy limit below the number, by switching off lamps, twice laundrying, turn of the rice cooker when ironing cloth, and etc. This strategy is the part of energy practice driven by cognitive norm, in which reluctance of new technology despite economically possible.

4. Conclusion

From the discussion above, in order to create comfort, the inhabitants arrange their domestic unit to the maximum-wise of the space. Modifications of the domestic are the energy practice that mostly found in detail, to response a certain level of thermal comfort, i.e. cool or very cool. This practice, i.e. strategy, though consumpt more energy and also may decrease the spatial quality, health or safe related condition in the domestic unit. A circular cummulative can takes effect and eventually becomes shortcoming for the inhabitants, e.g. encourage higher energy consumption.

The electronic appliances utilized in the domestic unit are mainly appliances that can provide thermal comfort, such as fan and/or air conditioner. The very extensive use of cooling appliances reflects the thermal condition and thus basic need in this vertical housing. Comfort i.g. thermal comfort therefore plays a dominant role in the limited domestic environment as the cognitive norm that drives energy consumption.

Thereafter are the appliances that are necessary to fulfill their basic domestic activities and also entertainment needs, such as refrigerator, television, stove/rice cooker, ironing equipment, and these should be considered to create a suitable energy effective housing design. These appliances are used in a similar pattern regardless the type of the units and the household's income. They only vary in the number and the duration, which means energy practice that relate to energy and cost saving. They tend to have controll in energy consumption for household needs, such as cooking and washing. Meanwhile for the need to be thermally comfort, they incline not to have strict strategies in energy consomption and more likely uncontrolled.

The limited supply of energy and physical setting can be seen not as obstacles, but rather a setting, where inhabitants can create stretegies. Since the educational background is unknown in this study, a design that provides safety and flexibility for modification and installation in electrical or other power supply is needed. Due to the facts that the majority of the residents are increasing the electrical power supply, it can be seen that some electronic appliances are taken as the standards of energy need and used as benchmark for the energy design in domestic scale, such as ubiquitous power line connection and other possibilities in creating smarter

compact unit dwelling integrated with energy supply and need.

As the thermal comfort is as basic need in middle low-income households, the awareness of the good energy culture as basis for energy consumption, going green or sustainability can be considered not yet an issue in vertical housing Kemayoran. This also reflects the need to reduce the reluctance of new technology through better information material.

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