Indonesian Building Codes and Its Influence on Future Electricity Demand

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Abstract: The direct and indirect heat load through enclosure materials, internal load (sensible and latent heat) plays an important role in the building life cycle energy. This paper evaluates the effect of Indonesian building regulation for building envelopes and predicts the possible future electricity demand scenarios as well as policy improvement.
A building simulation program (ECOTECT^{TM}) is used to simulate the cooling load scenarios based on different buildings envelope materials. Due to the competitive price and simple production processes concrete block is a very appealing material for Indonesian buildings; its Overall Thermal Transfer Value (OTTV) is lower than the current walls material (brick). The result for the hottest month the cooling load effect shows a concrete blocks reached 5,617 Wh/m^2 compared to 2,363 Wh/m^2 for bricks.
The result on alternatives materials as well as codes improvement then applies on the electricity supply-demand scenarios planning. The development on scenarios planning based on the information from economic analysis (using Granger-causality test) in order to find out the influence on economic growth in electricity consumption in Indonesia. The potential of electricity cost reduction then calculated by using LEAP (Long-range Energy Alternative Planning) an integrated modelling tool.
The building codes standard OTTV based is beneficial particularly on the skin load-dominated buildings (single landed) in non-humid ambient condition whereas most of the residential high rise buildings in tropical countries are internal load-dominated. The results show that low OTTV values do not directly reduce the electricity consumption in high-rise buildings, however higher OTTV value means higher electricity consumption in single landed buildings. The future electricity demand in Indonesia mainly consumed by industrial sectors however based on the prediction the room for improvement in residential sector is high. The improvement through material improvement and policy improvement will reduce the electricity consumption up to 40 per cent and up to 30 per cent less cost.

Keywords: Buildings, policy, electricity demand, Indonesia.

1. Introduction

Indonesia has strong electricity and economic growth causality relationship, the percentage of electricity share in the country dominated by residential sector [1]; moreover the residential growth proves to be in line the economic growth. Based on United Nations (UN) data the economic growth in the past two decades reaches seven percent in average, therefore the increases of electricity demand seem to be unavoidable.

According to a UN report, in the year 2010 urban living will surpass rural living and by the year 2030, 60% of the world population will live in urban areas [2]. These changes will be particularly visible in Asian countries where the economy is increasing rapidly. The urban living will lead to the increases of the heat island effect, reducing air quality and increase in the demand of cooling systems in hot and humid countries and heating system in cold regions.

Based on the housing and household statistics (Susenas) [3] surveyed in 2004, the total number of Indonesian households reached 56.6 million, of which 45 percent were urban households with 80 percent of them being single landed types, 2 percent is apartment/condo type [4], and the remaining 18 percent is multi-storey or multi-purpose buildings. 83 percent of the urban households were TV users and 40 percent AC users. The number of households using AC came to 8.1 million. In line with the economic development as well is the impacts of warming the globe, the use of AC will increases. The graph below shows the number of household with 3.2 percent growth as well as the increase of AC owners in 6-7 percent.

In Indonesia, about 30-50 percent of the total building electricity consumption is dominated by AC (air conditioner) use [5-6]. It has been reported that the energy use during building occupation is seven times greater than during the construction and material production phase [7,9]. Thus, the energy use during the occupation phase needs to be analyzed. This study will assess the influences of Overall Thermal Transfer Value (OTTV) and its utilization phase, and then predict the future energy demand.

OTTV is applied for measuring the energy utilization in the building during design phase. The method is very useful for the skin load-dominated building, as in some cases the external heat can reach more than 50 percent from the overall cooling load [10] and only 10-16 percent for some cases in high-rise buildings in Indonesia [7] where the internal load and infiltration have more share of heat. For hot and humid areas the internal load, infiltration and humidity have a higher contribution to the cooling load compared to the dry and arid areas. A study in Japan also showed similar results [11]. Most of the researches using OTTV to measure the energy requirement and energy utilization on the conditioned buildings have shown a strong correlation between OTTV and energy performance, only few considering the correlation to CO_2. A study in Hong Kong [12] showed the pre-calculated OTTV has inherent deficiencies, as the interacting effects among heat gains from different envelope elements and internal sources, and the impact of room configuration cannot be properly accounted for. It is therefore is subject to uncertainties and is inconsistent with the envelope performance. However studies in arid and dry areas such as China and Bahrain show strong correlation between the energy performance and OTTV [10-11,13]. Also some studies in Thailand [14-15] indicate a strong correlation between OTTV and energy performance. The purpose of this paper is to study the correlation between OTTV and electricity consumption, the future prediction and scenario planning also estimated.

2. Experimental

2.1 Data collection

The following primary data were collected in Indonesia - electricity bills, usage of the air conditioner (AC) and other electric appliances (including quantity, efficiency and year of production), building material properties particularly building envelopes material, building orientation and form. Data on electricity utilization behaviour were collected using open interviews and structured questionnaires covering 35 apartments in Jakarta; with floor area varying from 75 to 100 m^2 and having 2-3 bedrooms (two of them mostly air-conditioned) and one living room (mostly air-conditioned). The monthly family income of the studied houses ranged between 10-15 million Rupiah (USD 1,100-1,650).

The building life cycle energy was assessed using Life Cycle Energy Analysis (LCEA) a Life Cycle Assessment (LCA) based assessment on the cradle to grave of the building. The assessment is starting from materials extraction up to end life of the building (includes transportation and construction phase). The energy assessment during utilization phase also assessed, by using ECOTECT^{TM} a dynamic building simulation. The influence on the OTTV and energy in the building then assessed separately.

Regulation on building codes such as Indonesian National Standard (SNI) also collected and analyzed. The future energy supply based on the current renewable energy potential and government long-term plan also collected and assessed. The historical data on economic indicators and energy also gathered through international organization sources (International Energy Agency, UN, Asian Development Bank and World Bank) as well as national database. The scenario was developed by using Long-term Energy Alternatives Planning (LEAP).

2.2 Energy building simulation and studied model

Electricity usage was assessed in order to extract the information of the cooling appliances utilization. The electricity for cooling and the cooling load caused by sensible heat (related with OTTV) was computed using a dynamic building simulation program, ECOTECT^{TM} [16]. For this study, ECOTECT^{TM} was used only to calculate the load associated with building envelopes. It performs simulations based on the input parameters such as average temperature setting, occupants, material for enclosure, humidity, AC efficiency, AC utilization pattern, zone infiltration, external infiltrations, air speed and internal heat (appliances and human). The simulation was carried out for the whole year as the climate is hot and humid throughout.

The studied house (Figure 1) has approximately 10 m^2 of air-conditioned room with one living room placed together with kitchen. The wall thickness is 140 mm for brick walls and 110 mm for con-block walls. The ceiling is made from local gypsum with 3 mm thickness, roof and windows/doors frame are made from wood. Both houses use the same material for roof frame, ceiling and window glass; namely wood, gypsum and clear glass, respectively. The study assumed the appliances to be the same in every bedroom and the occupant rate for using the rooms was also similar. The total number of persons staying in the air-conditioned room during night time is two and none during daytime (weekdays) and fully occupied day and night during weekend.

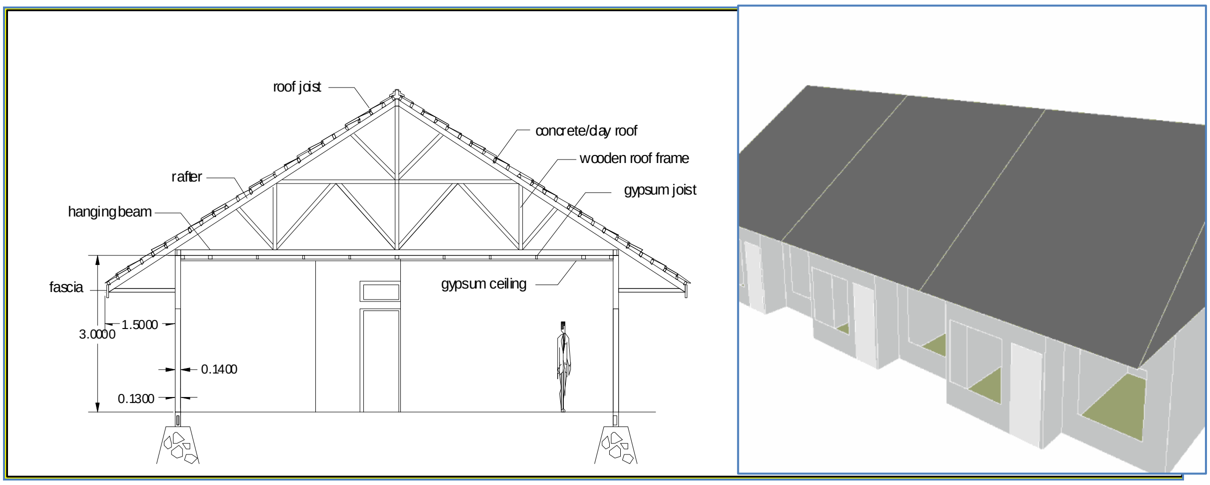

Figure 1. Single landed house studied model.

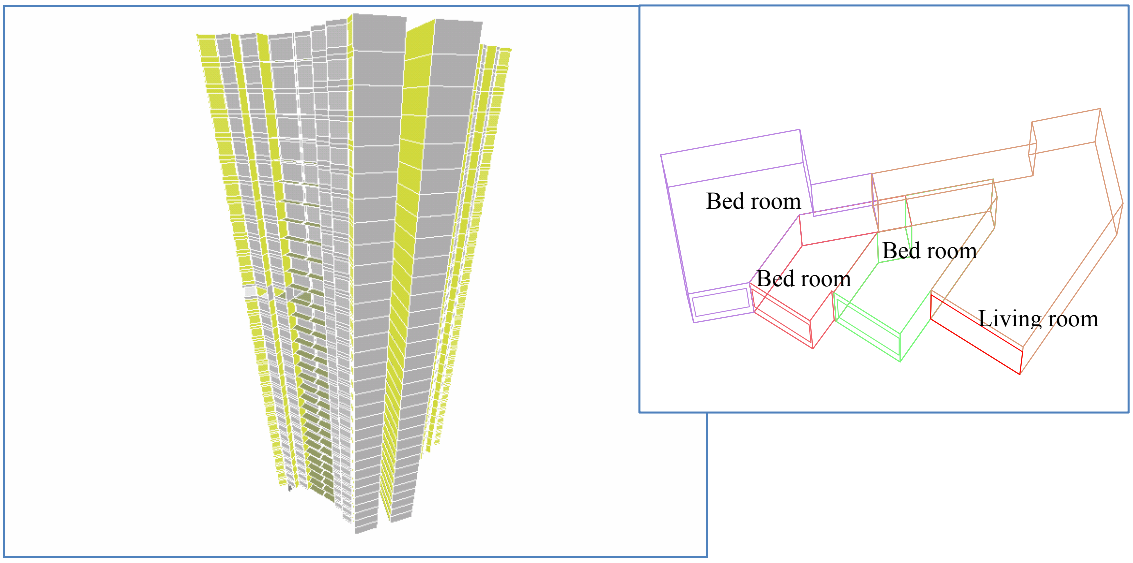

Figure 2. High rise studied model.

The high-rise model, studied in this work represents one of the common high-rise apartments in Indonesia (see Figure 2). It is located on the 20th floor facing north and has approximately 85 m^2 floor area with 53.17 m^2 of air-conditioned space (two bed rooms and living room). The kitchen is located together with the living room without separation wall. The wall has 10 mm plaster (outer side), 110 mm local bricks and 10 mm gypsum plasterboard with 50 mm air gap between bricks and gypsum. The ceiling is made from local gypsum with 3 mm thickness. All of the scenario options use the same material for floor, structure, windows and door frame and boards (aluminium for frame and wood panel for doors) and clear glass for windows. Every bedroom has the same appliances and a similar occupancy rate. The total number of persons staying in the air-conditioned room during night time is four and none during daytime (weekdays) and fully occupied day and night during weekends.

2.3 Building regulation (OTTV)

The latest Indonesian building codes were developed by the Indonesian National Standard Organization (BSN); one of the codes directly regulates the energy conservation for building envelopes (SNI: 03-6389-2000) under small task force organized by the department of mining and energy at the directorate general energy development in the Ministry of energy, mineral and resources. The other building related codes but not directly related with the buildings envelopes such as energy conservation for air flow in the buildings (SNI: 03-6390-2000) and ventilation and air flow design procedure for buildings (SNI: 03-6572-2001) have also been introduced by the organization. SNI: 03-6389-2000 refers to 1980 ASHRAE, ASEAN-USAID projects in 1992, the Singaporean handbook on energy conservation in buildings and building service 1992 and BOCA (International energy conservation code) 2000. The code mainly considers the OTTV and RTTV (Roof Thermal Transfer Value) based formula, the OTTV formula expressed as:

$$OTTV = \alpha\,[(Uw\,.\,(1-WWR)].\,TD_{Ek} + (SC\,.\,WWR\,.\,SF) + (Uf\,.\,WWR\,.\,\Delta T) \quad (1)$$

Where OTTV = overall thermal transfer value (W/m^2); α = solar radiation absorption coefficient for opaque materials; Uw = opaque thermal transmittance (W/m^2); WWR: Windows Walls Ratio; TD_{Ek} = opaque equivalent temperature difference

SNI: 03-6389-2000 for building envelopes codes is not stand-alone, the SNI: 03-6390-2000 and SNI: 03-6572-2001 support the standard in terms of the technical choices of optimizing and designing the measures of the cooling load and energy conservation through air conditioning system. The calculations for cooling load follow the Total Equivalent Temperature Difference (TETD) method and Cooling Load Temperature Difference (CLTD) method. Both are based on the temperature difference, either caused by solar cooling load factor (SCLF) or internal cooling load factor (CLF). In reality most of the conventional air conditioning units in Indonesia are designed for hot and dry climate (sub tropical) not hot and humid climate; less than 25 percent of the latent heat absorbing capacity is from the overall humidity potential in the air-conditioned room [17]. Some approach on improving the AC appliances by adding heating coil or electrical heater, these approaches categorizing very expensive and high energy intensity [18].

2.4 Electricity demand scenario and planning

The current building electricity consumption is used as the base year for predicting the future electricity demand through building codes scenario. The future electricity prediction based on business as usual scenarios (Reference) as base comparison; the input electricity on growth will be based on the information from causality inputs and LEAP modelling tools, as the growth of Indonesian electricity demand is correlated with the growth of its economic [19].

LEAP is a scenario-based energy-environment modelling tool. Its scenarios are based on comprehensive accounting of how energy is consumed, converted and produced in a given region or economy under a range of alternative assumptions; such as: population, economic development, technology and price [20]. The study use 2000 as base year and the 2050 for the end year, with the total population of 222 millions, 1,900 USD GDP per capita, assuming to have 58 millions household with 3.98 household size in average (urban and rural combined). Urban living will increases from 49.2 percent in 2008 up to 79.4 percent in 2050. The electrification currently is 85 percent and reaches 100 percent in 2050. 15 percent of the country electrification depends on the off grid and the remaining is grid connection. Currently 11.5 percent of electricity in the transmission is loss and reduce to 9 percent in 2050. The current reserve margin is 17 percent and will increase up to 30 percent in 2050. The installed capacity in the base year is 21 GW and will reach 415.6 GW in 2050.

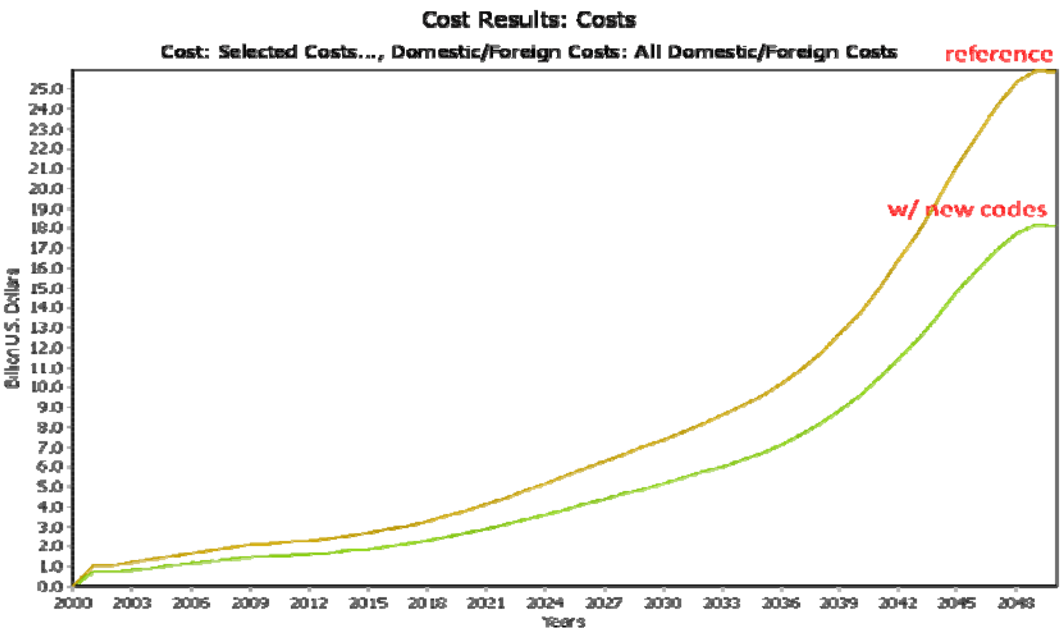

Figure 3. Electricity demand cost comparison between reference and the new codes.

3. Results and Discussion

The OTTV value as shown in table below represents the design value for typical landed house and apartment in Indonesia. Most of the value shows an average value close to the maximum requirement stated in the regulation (45 W/m^2) in SNI: 03-6389-2000.

The result on LCEA shows that clay based material has higher embodied energy compare to cement based material for landed houses, accounted 836.8 MJ/m^2 fl.area and 817.6 MJ/m^2 fl.area respectively. However the analysis on electricity consumption on the utilization phase proved opposites, houses with clay based material consumes less monthly electricity than cement based. The clay based material consumes 187 kWh compare to 198 kWh in cement based. The high rise building embodied energy shows the double walls has more energy compare to single walls per square meter of floor, 970 MJ/m^2 fl.area compare to 909 MJ/m^{2}fl.area, similar with landed houses, the monthly electricity consumption for double walls accounted less compare to single walls, 253 kWh compare to 321 kWh.

The cause of high electricity consumption on the clay based material in the landed houses due to concrete walls store more heat than bricks walls and are thus able to accumulate as well as release heat slower than clay bricks. Also the study proved that clay based material has less thermal storage than cement based materials, as the time lag influences the thermal transfer to the conditioned room, therefore during night time (when most of the occupants will utilize the AC will get higher accumulated heat then clay based houses). In case of high rise building the thermal resistance of single walls is less than double walls. Direct heat convection through indoor room is greater in single walls than double walls. However the time lag has less implication in case of high rise, since the thermal surface of high rise is much less compare to landed house by factor of 5 (depends on the façade which has direct expose to the ambient).

For landed houses the external load are responsible for 70 percent of the overall cooling load while the remaining is internal load. The external load mostly (50-60 percent) comes from sensible heat while the remaining is latent heat (depends on the ACH or air change per hour in the zone). The internal load responsible for 30 percent of the load and almost 90 percent out of it is latent heat. Moreover for the breakdown of the electricity load liable sources, the internal loads are responsible for 80 percent of the load in high rise building while the remaining is external load. The internal load itself also generated from many sources mainly is latent (which responsible of accumulated more than 90 percent, while 50 percent of the external load also latent heat (depends on the ACH).

The result on the energy planning and scenarios revealed that the improvement of building codes (not only for skin load dominated building, such as landed houses) will reduce the overall national cost of electricity in more than 30 percent (see figure below) in year 2050 or more than 198 billion US$ up to 2050. The result on the scenario planning based on the assumption where the new building codes starts to be implemented in the base year (2000) and conservatively continue to implement firmly for every new building development in the country. The scenario based on the assumption ion the new consideration on internal load codes and efficient cooling system as well as building envelopes form and material improvement, by using existing technology assume to save the energy by 25 percent. By the following years the assumption on more reduction such as higher degree of skill during design process will increase the energy saving up to 50 percent [21].

The proposed new codes used in the scenario planning includes the improvement of the AC system which containing more energy efficient system which absorb more humidity, also includes the passive humidity buffer. The passive humidity buffer is mainly done through the improvement and replacement of the current indoor building materials (mainly gypsums for ceiling and partition), which has very low humidity absorbance capacity [22], and replaced by high humidity absorbent capacity. Figure 4 shows the result of the improvement progressively increases in line with the increase of the awareness as well as improvement of the building codes.

4. Conclusion and Recommendation

These results suggest that OTTV alone is not enough to measure the energy performance due to cooling load in the building since the major load in tropical countries is humidity especially for most of the typical high-rise and multi-storey buildings. Only less than 20 percent of the external heat gain is responsible of the cooling load in case of high-rise buildings.

OTTV method works well for measuring electricity performances in low humidity, temperate climates. In high humidity zones such as tropical countries buildings with low internal heat (occupied during daytime and weekdays) and high percentage of roof or walls areas such as single landed, multi-storey building but not the high-rise building, the OTTV method to measure the energy consumption is not proven well.

As the studied baseline and alternative building materials in the study are categorized as skin load-dominated buildings type the performance on its OTTV should still be analyzed as part of the national code of practice. Some observations regarding the influence of OTTV with the energy performance and CO_2 reduction in building are:

1. There is no direct evidence in less exposed façade area (high rise building) on the OTTV value and the electricity consumption. Due to the low influences of the external heat on cooling loads in hot and humid weather. However in case of landed houses as more skin-load dominated type of building, the OTTV influence cannot be negligible.

2. For skin load-dominated buildings the sensible and latent may have similar consideration in terms of cooling load. Since the load from the envelopes reaches 70 percent and the remaining is the internal load. The building codes regulation in tropical countries should have different approach rather than having the simplification of the codes.

Table 1. OTTV value in typical Indonesian buildings.

Type of model and material	U-value [W/m^2.K]	Time lag [hours]	Width [mm]	Density [kg/m^3]	Conductivity [W/m.K]	Specific heat [J/kg.K]	OTTV [W/m^2]
Bricks w/ gypsum board	1.12	4					45.92
lightweight bricks			110	950	0.27	840	
Bricks	1.58	3	110	950	0.27	840	52.20
Concrete block	1.85	4	110	1800	0.785	657	48.97
air gap		negligible	50	1.3	5.56	1004	
gypsum			10	1100	0.65	840	
Plaster			10	1250	0.431	1088	
Clear glass standard (92% transparency)	5.44	negligible	6	2300	1.046	836.8	40.83
Glass 70% transparency	5.44	negligible	6	2300	1.046	836.8	40.83

3. Improvement on the cooling system (mainly AC) of which considering the RH in more than 75% rather than based on ASHRAE which the condition of the climate is divided into cold and hot condition with RH in approximate 60 percent

4. Additional explanations on the cooling system (AC) for adding device (such as heat pipe and solar cooling) in order to increase the appliances capacity to bear the high RH condition

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