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Building Energy Consumption in Malaysia: An Overview

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Abstract

Buildings consume up to 40% of the total global energy. By the year 2030, the consumption is expected to increase to 50%. In Malaysia, buildings consume a total of 48% of the electricity generated in the country. Commercial buildings consume up to 38,645 Giga watts (GWh) while Residential buildings consume 24,709 Gwh. Demand for electricity in the country is expected to rise from 91,539 GWh in the year 2007 to 108,732 GWh in 2011. By the year 2020, the energy demand in Malaysia is expected to reach 116 Million tons of oil equivalents (Mtoe). Carbon dioxide (CO_2) emission in the country has increased by 221% ,which lists the nation at 26th among the top 30 greenhouse gas emitters in the world. Literature studies indicate more than 50% of this energy is used in buildings for occupants comfort (air conditioning and refrigeration). Energy consumptions by residential occupants can be minimized if energy usage is considered. This paper aimed at reviewing some literatures on energy consumption in the residential buildings in Malaysia and suggests ways of improving the energy usage by the occupants.

Keywords: Energy; occupants; behaviors; residential buildings

1.0 INTRODUCTION

The demand for housing is increasing all over the world because of the growing population. This leads to rise in the demand of energy use by the housing occupant's globally. The construction sector is the major contributor of energy consumption. As a result of the increasing demand of housings, building energy consumption has recently become a major issue of concern over carbon dioxide and greenhouse gas emissions [1].

The International Energy Outlook report on the current position of the global energy consumption reveals that energy will continue to grow by 56% in-between the year 2010 and 2040. Moreover, the total global energy will increase from 524 quadrillion British thermal units (Btu) in 2010 to 630 quadrillion Btu in 2020. This will continue to increase to 820 quadrillion Btu in 2040 [2]. European building sector is considered as the largest consumer of energy. The sector is using up to 40% of the world's energy generated. In addition, buildings consume 25% of the timber in the region and 16% of the drinking water in the region [3]. Moreover, 40% of the entire energy use and 36% of whole carbon dioxide emissions come from European buildings [4]. Heating, cooling and lighting appliances in buildings accounts for one third of the world primary energy demand [5]. The United States Department of Energy (DOE) in 2010 estimates that 74% of the electricity usage and 40% of the carbon dioxide emissions in the US come from buildings [6].

The increase in the number of buildings in Malaysia has a great impact on national development but it also increases the energy demand [7]. Statistical record by tenaga Malaysia shows that 94% of electricity generated in the country is by fossil fuels and it is expected that the figure will be unchanged over the next decade [8] research showed that buildings consumes up to 40% and beyond of total world energy perticularly electricity, and release up to 1/3 of global contamination/ greenhouse gas (GHG) through fossil fuels burning in generating electricity [8]. Rozana [9] highlighted that greenhouse gas emission in the Malaysian existing buildings and its communities had contributes to over 40% carbon gases to the environment.

Chua and Oh [10] study reveals that the total electricity generation and consumption in Malaysia is expected to increase more in the near future. The energy generated in 2000 is 69,280 Gwt. In the year 2010, the energy generated increased to 137,909 Gwt. This is because of the country's increasing energy demand from 1243.7 to 2217.9 Pascal joules (PJ).

The energy demand in Malaysia increased due to the change of policy by the government. From agricultural based economy to technological. In 2009, Malaysian population is estimated to be 25.4 million people. By year 2020 the population is expected to be around 32 million people. The expectation is that 75% of this population will live in urban areas. This signifies that the rate of energy consumption will increase due to the usage of modern home appliances, particularly Air conditions and refrigerators

[11]. Furthermore, lighting becomes the second electric power consumption after air conditioning and refrigerator [12].

According to world fact book, 118 billion kWh was produced by Malaysian Government. On the other hand the electricity consumption of Malaysians is around 112 billion kWh [13]. CO_2 emission in Malaysia has increased by 221% in 2004. This increase in carbon emission list the country as the 26th nation in term of carbon and greenhouse gas emission [14]. Malaysia is presently releasing a sum of 216,804 tons of carbon emission in a year, which is 0.69% of the total world emission.

2.0 ENERGY GENERATION IN MALAYSIA

Table 1 indicates the gross generation and consumption of electricity for Malaysia in 2012. The electricity consumption is less than the generation with about 18GWh. The electricity generated in the country is around 135GWh and the consumption is around 117GWh. The advanced development in Malaysian economy is dependent on the continuous energy supply. Consequently, any shock or shortage of energy supply in the country will have an unfavorable result in the country's economy [11].

Table 1 Regional electricity generation in Malaysia, 2012

REGION	ELECTRICITY GROSS GENERATION		ELECTRICITY CONSUMPTION		AVAILABLE CAPACITY	PEAK DEMAND	
	GWh	%	GWh	%	MW	MW	%
PENINSULAR MALAYSIA	117,797	87.7	102,174	87.7	21,044	15,826	33.0
SARAWAK	10,824	8.0	9,237	7.9	2,265	1,161	95.1
SABAH*	5,754	4.3	4,943	4.3	1,091	828	31.8
TOTAL	134,375	100.0	116,354	100.0	24,400		

Source: Tenaga [15].

The consumption of electricity by the major sectors which are industries, commercial and residential buildings are shown in table 2. World Green Building Council stated that buildings are the major single largest contributor to the global warming. It accounts for one-third of global carbon emissions. In Malaysia, buildings (commercial and residential) consume 13% of total energy and 48% of electricity consumption [16]. Tenaga [15] highlighted that building structures in the country consume a total of 54% of the total electricity in the country. Commercial buildings consume 33% and the residential buildings 21%. A total of 38,645 GWh was consumed by commercial buildings. On the other hand, residential buildings consume a sum of 24,709 GWh. The table below shows the energy consumption by various sectors in the country.

Table 2 Regional and sectoral electricity consumption in Malaysia, 2012

REGION	INDUSTRY GWh	COMMERCIAL GWh	RESIDENTIAL GWh	TRANSPORTATION GWh	AGRICULTURE GWh	TOTAL GWh
PENINSULAR MALAYSIA	45,357	34,696	21,536	241	344	102,174
SHARE (%)	44%	34%	21%	0%	0%	100%
SARAWAK	5,554	2,026	I,657	-	-	9,237
SHARE (%)	60%	22%	18%	0%	0%	100%
SABAH	1,504	1,923	1,516	-	-	4,943
SHARE (%)	305	39%	31%	05	05	100%
TOTAL	52,414	38,645	24,709	241	344	116,353
SHARE (%)	45%	33%	21%	0%	0%	100%

Source :Tenaga [15]

3.0 REVIEW OF RELATED LITERATURE

Steemers and Yun [17] and Yu *et al.* [18] reported that six factors influence building energy use:

i. Climate (outdoor air temperature, solar radiation etc.)
ii. Building orientation
iii. Building services and energy systems (e.g space cooling/heating hot water supply etc.)
iv. Building operation and maintenance
v. Occupants activities and behavior
vi. Indoor environmental quality

However, a recent research by Kavousian *et al.* [19] identified four (4) major categories of determinants that influence building energy use as follows;

i. Weather and location
ii. Physical characteristic of the building
iii. Appliance and electronics stock
iv. Occupancy and occupant's behavior towards energy consumption.

3.1.1 Weather and Location

Climatic zone and daily outdoor temperature changes according to the weather condition and location of a particular country. In Malaysia, the tropical climate is observed throughout the year and the temperature ranges between 22^{O}C to 32^{O}C [20]. However, the annual mean air temperature is 27^{O}C [21].

3.1.2 Physical Characteristic of the Building

This factor considers the type of fuel use for water heating as well as the level of insulation used in the building. This determinant takes a very long-term investment when it comes to modification.

3.1.3 Appliance and Electronics Stock

This factor considers air-conditions, refrigerators and computers used in the buildings. This determinant takes a medium to short-term investment when it comes to modification.

3.1.4 Occupancy and Occupant's Behavior Towards Energy Consumption

Stern [22] mentioned that research conducted on buildings in respect to energy saving are uncertain and ineffective. This is because of the behaviors of the occupants. Research conducted shows that most of the organizations has mainly concentrated on the managerial policy making, with little emphasis on the occupants behavior towards energy efficiency [23]. Energy efficient buildings are not limited to design and construction alone. Occupant behavior can easily influence the consumption.

Energy Efficiency can serve as environmental control strategy of existing buildings in the sustainability agenda [24]. In an effort for ensuring good performance in term of energy efficiency of buildings, engineers should consider occupants relations with building control systems [25]. This is because people in developed countries spend 80-90% of their time indoors[26],[27]&[28]

It is very difficult to predict the level of occupants' interaction at individual level, rather, the use of patterns for a group of occupants and general control-related behavioral trends. The trends and patterns assist tremendously in measuring the environmental parameters such as indoor and outdoor activities [29]. When behavior is frequently repeated, it is no longer requires deliberative evaluation, because it becomes "a habit" [30]. This shows that energy conservation in relation to occupants' energy usage can be complicated and difficult to measure. A lot of energy goes to waste due to occupants' behavior [31, 32].

Occupants' activities and manners towards energy consumption is the major determining factor of residential building consumptions. Some behavioral determining factors are easy and temporary (e.g. setting of thermostat). While other determinants are associated with long-standing effort and impact (e.g., buying energy-efficient appliances).

3.2 Energy and the Malaysian Climate

According to English Encarta dictionary, climate is defined as a typical weather in a region [33]. Malaysian Meteorological Department (MMD) had characterized Malaysian climate as one with high humidity, harsh temperature and abundant rainfall. In Malaysia it is very rare to have a complete day with complete clear sky even during period of dry weather. It is unusual to have a few days without sunshine. [34].

Malaysia is located in between latitude 4^o 12' N / 101^o 58' E. This makes Malaysia 8hours ahead of Greenwich Mean Time (GMT). Because of the position of its latitude and longitude, it has a variation in temperature ranging from 89.6°F (32°C) in the day time, to 71.6°F (22°C) in the night, with little or no variation in temperature throughout the country. Several studies indicated that ambient temperature plays a vital role in relation to energy consumption of air conditioning system [35].

Rozana [36] added that Malaysian is blessed naturally with plentiful sunshine and high solar radiation. The country receives 6 hours of sunshine per day on average, with a daily solar radiation range from 14.90 Mjm^{-2} to 22 Mjm^{-2} on mean average. The country is located in hot-humid tropical region with much depleted wind speeds, and low variation of indoor air velocity. Air velocity in buildings only range between 0.04 m/s and 0.47 m/s, which is quite insufficient for indoor air movement [37]. In Malaysia the major concern on energy efficiency is focused within these major sectors; transportation, industrial manufacturing, residential and commercial building design [38].

Malaysia experienced high humidity and hot climate throughout the year. For occupants to survive this harsh climatic condition, Malaysian traditional houses were used for residential purposes. These houses were popularly known as the Malay house. These houses were built with lightweight materials such as wood and thatches. In addition, very wide openings of windows are made for proper natural ventilation. Nowadays, Malay traditional houses are hardly seen in city areas due to technological advancement. However, many of these building types are still in existence in the rural areas. Majority of the modern houses in Malaysian towns and city areas today are concrete and brick houses [39].

These modern houses were built as clusters, condominium or terraced buildings with inadequate ventilation. Because of this reason, occupants have air conditions as the only solutions to their ventilation problems. The major issue of concern is ensuring sustainable development through well-organized energy usage, energy wastage reduction and encouraging the utilization of renewable energy [10].

Malaysia experienced a rapid economic boost and technological growth and development. Subsequently the amount of energy usage has been increased. A research piloted by Centre for Environment Technology and Development in Malaysia (CETDEM) indicated that air condition and refrigerator take up nearly 70% of the average building electricity usage. Air condition is the largest consumer of electricity in Malaysian residential buildings[40].

The economic growth of any country is measured by Gross Domestic Product (GDP). Malaysian GDP is in correlation with the amount of energy consumption in the country..

3.3 Malaysian Modern Residential Houses

The Malaysian modern residential houses are mainly terraced, cluster or condominium buildings. Basically these types of buildings necessitate air- conditioning to survive the hot tropical climate unlike the Malay traditional houses. Malaysian census (2000) shows a dramatic increasing number air-conditions usage in residential households. The census result shows that, in 1970 the number of houses with air condition in the country is just 13,000. This number increase to 229,000 in the year 1990. In addition, this number suddenly rise to 775,000 in 2000 [21]. In addition, Yadollahi [41] highlighted that modern buildings in Malaysia are planned and designed to meet high standards with minimum maintenance standards.

According to Agarwal [42], two major approaches should be employed in reducing energy consumption of residential building. The first one is by enhancing the energy efficiency design of the devices. This involves replacement of the existing devices. A good example is by replacing incandescent and fluorescent lights with Light Emitted Diode (LED) and energy efficient Heating Ventilation and Air Condition (HVAC) in our buildings. The second approach is improving the existing systems efficiency in reducing the amount of wasted work. This includes the switching of lights, devices and equipment after usage [38].

3.4 Occupant's Behavior

One of the challenges for achieving the desired goal towards energy efficiency of buildings is the inconsistency of the behaviors of the occupants. Occupants of buildings can influence energy usage in different ways [43].

Buildings in United states of America consumes up to 40% of the total country's energy [44]. This is similar to the energy consumed in Europe as well. HVAC systems, lighting system and some heavy appliances are the major drivers that attributes to residential energy consumption. Besides, researches based on simulation software's indicates occupant behavior with buildings plays a major role in building energy consumption [45]. According to Chakraborty [46] between 2 to 20% of the 40% of energy consumed by buildings is misused through ineffective appliances. This refers to "electricity leakage" consuming energy without achieving the principal [42].

The increase in building energy consumption of residential sector in Malaysia is as a result of economy status of the occupants. Well paid job has influence occupants lifestyles [47]. The building energy behavior is influenced by many factors, which include building construction, weather condition, thermal property, physical materials used, lighting, HVAC and above all the occupancy and their behavior [48].

3.5 Building Energy Consumption Model

Building Energy Model is a simulation instrument which calculates the energy and thermal load used in either residential or commercial buildings. Building Energy Models are used in retrofitting of the existing structures based on the building architecture and HVAC as well as designing of new buildings. These days, building energy simulation tools can suggest the right construction materials to be used in a building. It also indicate unique energy saving methods like advanced window treatment for sun shading as well as energy renewable system [49].

However, most recent building model software's do not give the true picture of the occupants' actions on buildings and with the space utilization results. These tools depend on assumptions referring to human behavior [43].

Based on the review of the literatures, it was found that programs related to building energy have been developed in hundreds and are in use for the last five decades. However, much need to be done to come up with effective and reliable solutions [50].

Physical surrounding aspects driving occupants on building energy consumption are temperature, humidity, air velocity, noise, etc. [4]. Building energy models provide simplified and efficient prototype for future forecast on energy use in buildings. Some models calculate the amount of energy needed for heating, lighting and cooling in buildings. Models are used by variety of professionals like Architect, Engineers, and Municipalities. Recently, Energy auditors were interested in using models. All these experts relied on the correctness of the models for them to enhance energy saving plan for their clients [51].

The main challenging problem of the building energy modeling is the lack of proper and comprehensive detail validation. Recent studies show that most of the validation works were geared towards unrealistic cases under specific range of conditions. The idealistic or real life condition such as effect of occupants on energy usage still require more validation work [52].

Two parameters need to be considered while developing building energy model. The first one is the building as a structure. The second one is the occupants of the building. These parameters related to building should include the architectural layout, the materials used in building and HVAC equipment used in the buildings [51].

In addition, buildings are usually designed on the belief that occupants will use it as designed. However, occupants of buildings consider comfort more than energy conservation. Besides that, occupants of a building don't always acknowledge designers effort, instead they operate the building contrary to its original design [53] .

Every human being gives out heat and contributes to the pollution, (like water vapor, carbon dioxide etc.). Occupants of buildings similarly manipulate and interact with their environment and structures. A good example is the heating and cooling of their houses in order to get better thermal comfort [50] [54].

The energy use in buildings is completely complex, as buildings and energy types vary. However, most literature uncover that the main energy forms measure are heating/cooling load. The most frequently considered building types are residential, office and engineering structures, from small rooms to big housing estates[48].

Many parameters need to be considered while evaluating energy performance of a building. This may include passive solar system, indoor and outdoor condition, ventilation, thermal characteristic of the building and many more [55]. Building energy consumption is influenced by many factors. The major leading factors are occupants' behavior to energy usage and weather condition of a specified region [56].

Kavousian [19] added that weather condition, location of the building and the floor area are among the most important factors to be considered in residential building consumption. In addition to the determinants above, the use of air conditioning and refrigerators cannot be ignored.

■4.0 CONCLUSION

This paper highlighted some key issues and figures on the energy generation and consumption in Malaysian residential buildings. It also reviewed some literatures on the influence of occupants in relation to their buildings in term of energy consumption. It narrated some critical issues related to energy consumption and energy efficiency of a building in relation to occupants' behaviors. It discussed on some key issues related to energy usage by the occupants and the factors that determine building energy consumption. It also discuss on the determinants used for examining the effect of occupant's behavior in relation to building energy. The assumption was, the more occupants-related behavior towards energy usage was understood, the more realistic prediction of building energy consumption will be achieved.

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