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Time Series Data Analysis of Household Electricity Usage during El-Nino in Malaysia

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The aim of this research is to investigate the occupant's total electricity consumption as well as air conditioner usage behaviour in residential building located in Kuala Lumpur. The field survey was conducted between March to May, 2016 which is the hottest period during the year due to El Nino phenomenon. The results obviously show the heterogeneity of occupant's behaviour of energy usage. The total energy consumption is in the range of 9 kWh/d to 29 kWh/d. The measured energy consumption was compared with the outdoor air temperature.

1. Introduction

In recent years, the global warming phenomenon has become one of pressing issues on the globe, which has urged the improvement of energy efficiency in the building sector and increase of the renewable energy sources. Accurate prediction of time series data for total electricity consumption as well as air conditioner load which are strongly influenced by occupant behaviour has become essential for optimum design of renewable energy technology such as co-generation system at an affordable cost. It can provide the detailed statistics data including the variation of time patterns caused by the heterogeneity of occupant behavior in building sector. Over the past decades, many researches from temperate region have been carried out several field surveys on the occupant behaviour in terms of energy usage and air conditioner load. For example, Abreu et al. (2012) has proposed pattern recognition to identify occupant's behaviour associated with energy consumption based on family characteristics and weather condition. Tanimoto and Hagishima (2005) developed a logistic model based on probabilities of occupant behaviour such as switching on/off air conditioner. Furthermore, Yohanis et al. (2008) studied the impact of dwelling characteristics and occupancy on electricity consumption for 27 dwellings in Ireland over 20 months period. Firth et al. (2008) recorded the household electricity consumption and electricity consumption from different categories of appliances in 72 UK families to identify the trend in electricity consumption. Furthermore, Vassileva et al. (2012) analysed the sufficient data of electricity consumption in order to develop appropriate electricity-saving measures. However, there are still limited studies on tropical region have been reported. Therefore, the aim of this research is to reveal the occupant behaviour towards cooling and total consumption based on time series data of household demand in residencies area located in Kuala Lumpur, Malaysia.

2. Overview of field survey

The investigated target is ten dwellings located in a nineteen-story low-cost public apartment in Kuala Lumpur, Malaysia (KL, 3˚08' N, 101˚42' E). The total floor area in each target dwelling is approximately 60 m^2. The composition of air conditioner installed in every dwelling varies from one to two units which in different bedrooms and living room. Figure 1 displays a typical plan layout of a dwelling unit. The measurement is taken from March to May 2016 according to the consent approval from each dweller. In addition, the number of household is highly diverse from three to nine dwellers as shown in Table 1. The total number of days for this measurement varies from 52 to 87 d for each dwelling.

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Table 1: Summary of field survey

Dwelling ID[a]	Floor[b]	Number of household	Measured room[c]	Period of measurement (d)
D1	6th/19	7	LR	87
D2	17th/19	6	BR1, BR3	85
D3	6th/19	3	BR1	82
D4	18th/19	3	BR1, BR2	79
D5	3th/19	5	LR	77
D6	9th/19	4	LR	81
D7	10th/19	8	BR1	52
D8	3th/19	7	BR1, BR3	72
D9	8th/19	6	LR, BR1	82
D10	13th/19	9	BR3	81

[a] *Dwelling ID: D1-D10 are target dwellings*
[b] 6th/19: sixth floor of a nineteen-story building.
[c] *LR: Living room; BR1: Bedroom 1; BR2: Bedroom 2; BR3: Bedroom 3*

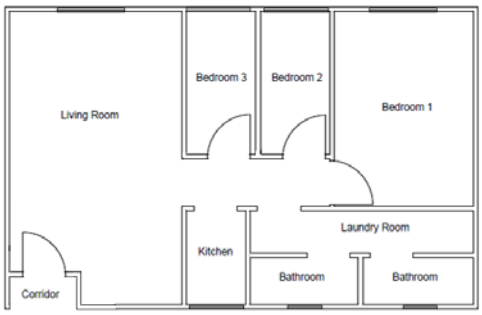
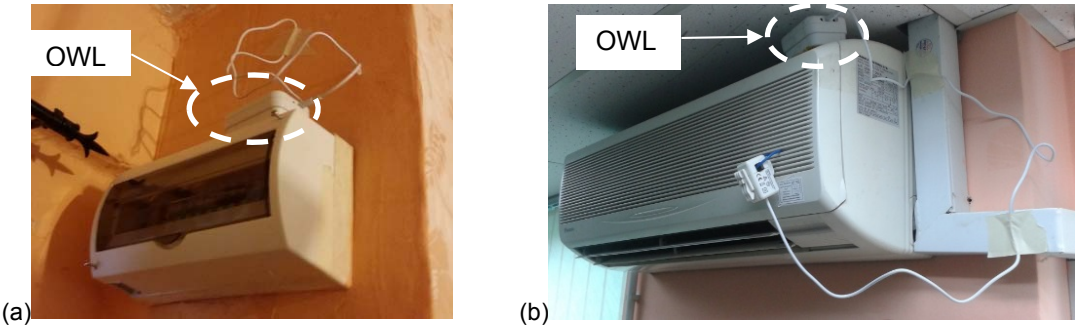


Figure 1: Typical plan layout of one unit dwelling.

3. Measurement items

The OWL power monitoring device is installed at the Miniature Circuit Breaker (MCB) to measure the total electric consumption of one whole house. At the same time, another OWL power monitoring device is also installed at certain unit of air conditioner to measure electric consumption when it is operated. These air conditioners are using frequently by the dweller. The duration of interval for electricity measurement set for one minute during the survey period. The photos of installation for these devices are shown in Figure 2. The outdoor air temperature is recorded by weather station per 10 min which is installed at 2.5 m above ground level located in University Teknologi Malaysia (UTM), KL. This weather station is located approximately 3.6 km from the target dwellings.



(a) (b)

Figure 2: Photo of installation for OWL power monitoring device at (a) MCB and (b) air conditioner

4. Result and discussion

4.1 Outdoor air temperature

The outdoor air temperature is fluctuated from 24 °C to 40 °C during the measurement period as depicted in Figure 3.The high temperature in daytime can reach up to 40 °C due to El Nino phenomenon which leads to scorching weather across Asia as well as east Africa and floods in South America. Syahidah et al. (2015) recorded that the daily average temperature was around 35 °C during this period on last year at the same weather station. It can be concluded that there is around 5 °C increment in daily average temperature compared to last year.

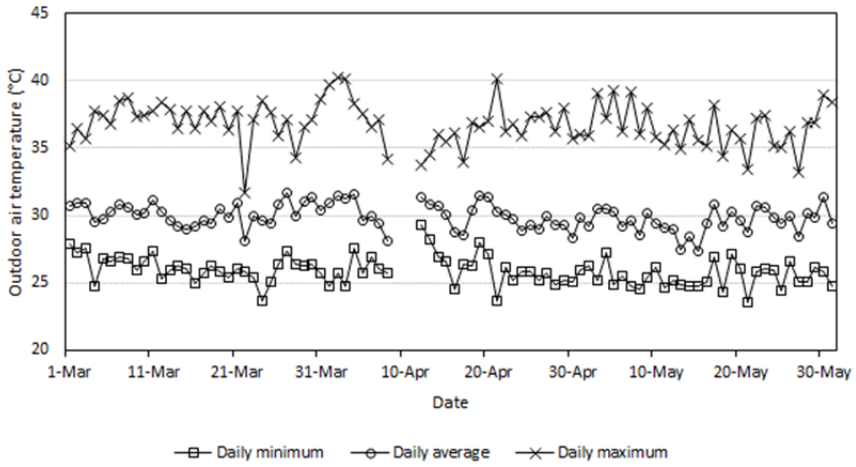


Figure 3: Variation of daily outdoor air temperature during measurement from March until May 2016

4.2 Daily statistics of electric consumption

Daily variation of total and air conditioner electric consumptions of ten dwellings is shown in Figure 4. The daily total electric consumption is fluctuated from 4.7 kWh to 38.0 kWh among each dwelling. The similar condition is also observed for air conditioner usage which is fluctuated from 0.2 to 23.7 kWh. It indicates the diversity of occupant behaviour for each dwelling. The daily routine, schedule of each residence, number of household and others could be the factors that contribute to these results.

Figure 5 exhibits the bar chart of daily average total and air conditioner electric consumptions of each dwelling during the measurement period. Each bar represents the average of energy consumption per day in each dwelling. The highest total and air conditioner electric consumption were recorded in D9 at around 29.4 kWh/day and 13.5 kWh/day, respectively. The lowest total electricity consumption was recorded in D3 at around 8.9 kWh/day. However, both D3 and D7 show only a small portion of air conditioner electric consumption at approximately 2.5 kWh/day. The similar trend of total electric and air conditioner usage in each dwelling were observed. This is because of the electric consumption for air conditioner is the most effective factor to the total electric consumption in these dwellings.

4.3 Correlation between electricity consumption and outdoor air temperature

Correlation between the average total electric consumption in a day for all dwellings and the daily statistics outdoor air temperature are shown in Figure 6. Daily minimum and maximum could be represented the data of night time and hot daytime, respectively. Similar graphs have also been plotted for air conditioner electric consumption as shown in Figure 7. These two graphs might reveal how the dwellers' behavior in energy use and the environment cooling is correlated with the outdoor temperature. Both total electric and air conditioner energy consumptions show a positive correlation with minimum and average outdoor air temperature. Such condition indicates that the occupant's behaviour of energy usage during night time might be dependent on the outdoor air temperature especially the air conditioner usage. In contrast, both electric consumptions show less correlation with daily maximum outdoor air temperature. This is due to the uncertainty of occupant's schedule during the hot daytime. Some dwellers might be using air conditioner to cool down the indoor temperature and vice versa.

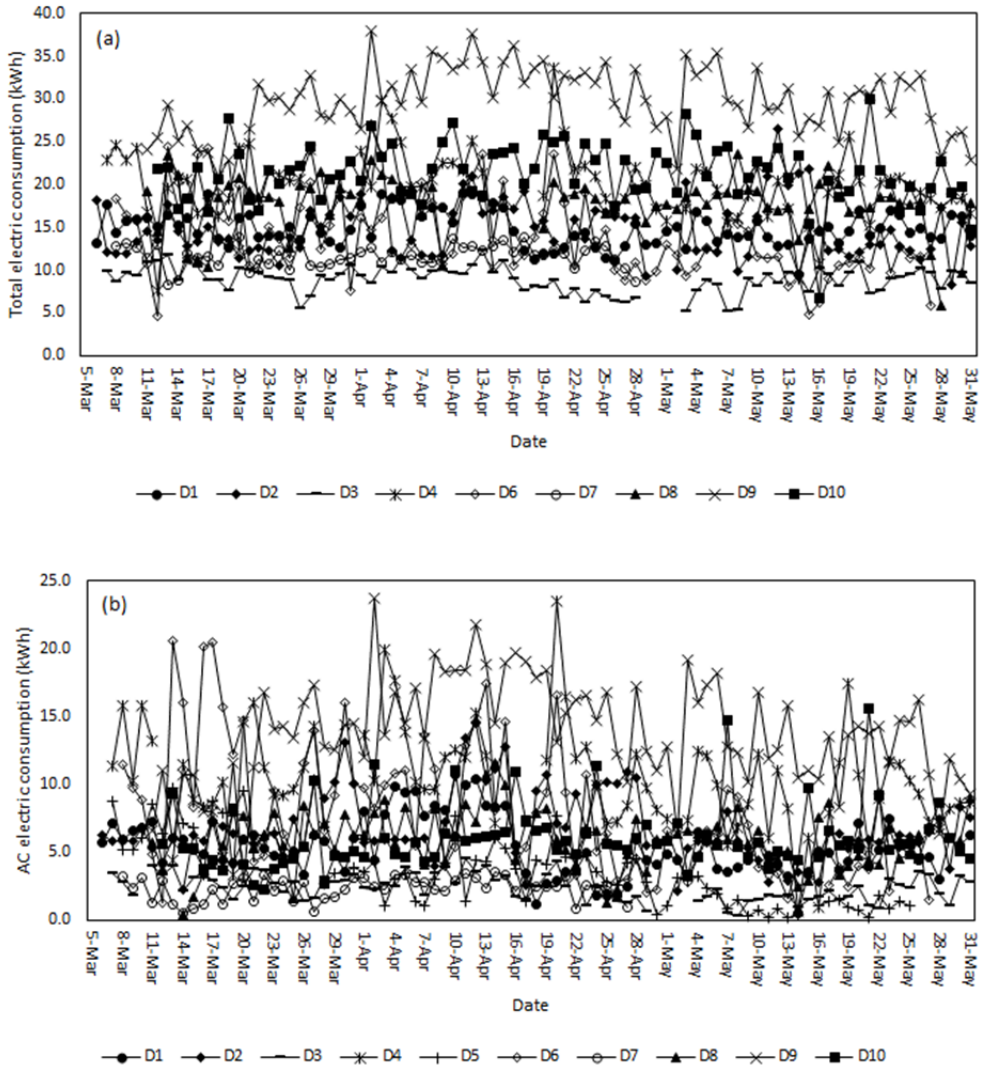


Figure 4: Daily variation in electric consumption of 10 dwellings from 5 March to 31 May 2016 (a) total electric and (b) air conditioner electric usage

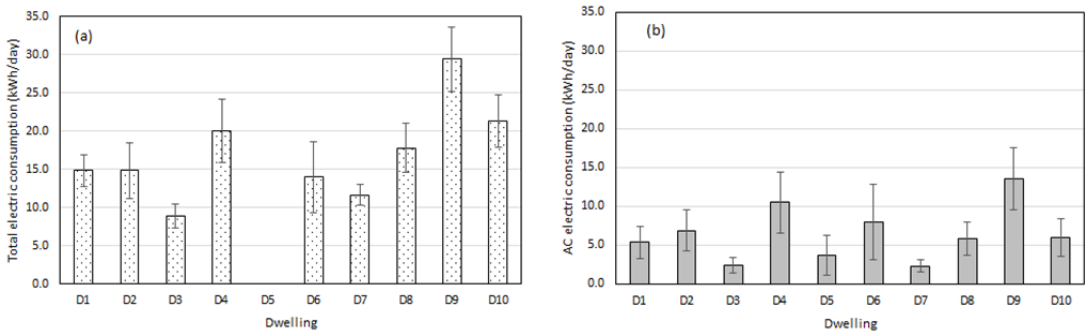


Figure 5: Daily average of electricity consumption in each dwelling (a) Total electric consumption and (b) air conditioner electric consumption. The error bars refer to the standard deviation among samples.

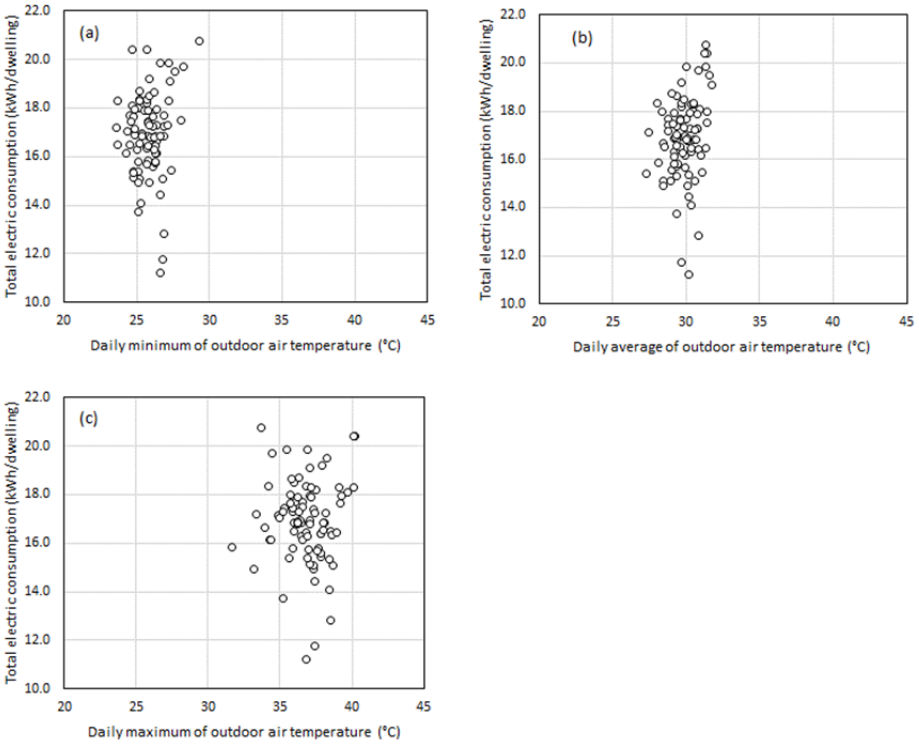


Figure 6: Correlation between total electric consumption and outdoor air temperature for 10 dwellings during measurement period. Data for (a) Daily minimum, (b) Daily average and (c) Daily maximum temperatures.

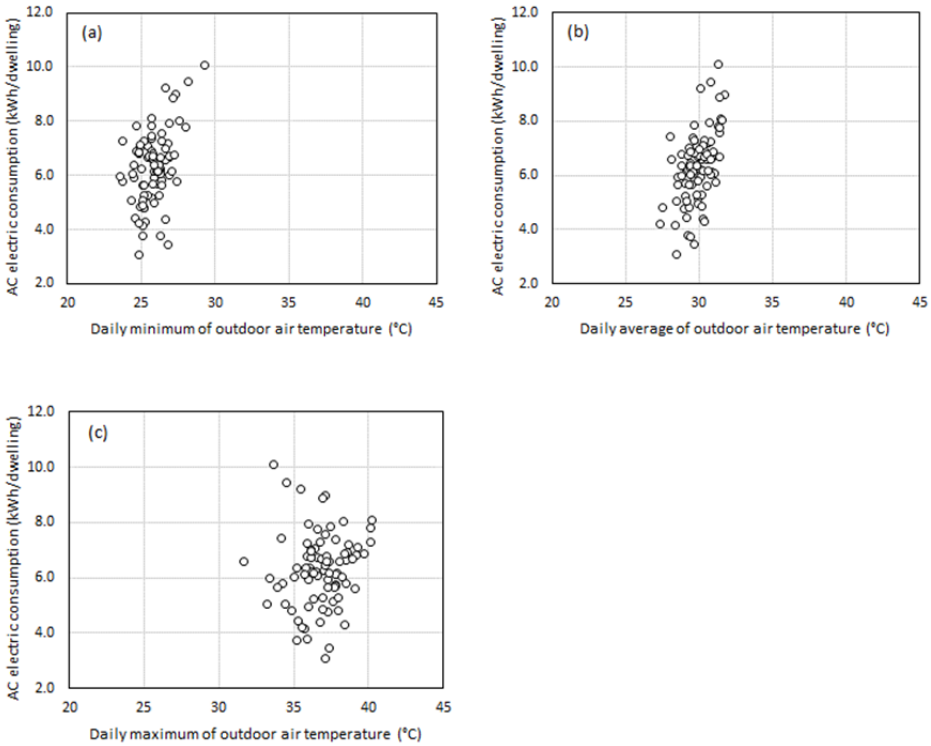


Figure 7: Correlation between daily air conditioner electric consumption and outdoor air temperature for 10 dwellings during measurement period. Data for (a) Daily minimum, (b) Daily average and (c) Daily maximum temperatures.

5. Conclusion

In order to investigate the behaviour of energy usage among dwellings in Malaysia, a field survey has been conducted. This field survey able to observe the time patterns of total electric and air conditioner consumptions in ten dwellings in Kuala Lumpur, Malaysia during the El Nino climate phenomenon. The results of energy patterns for total electric and air conditioner are clearly shown the diversity of occupant's behaviour in daily energy usage. The total electric consumption in each day for all dwellings is varied between 9 kWh/day to 29 kWh/day. Additionally, air conditioner is considered the major contribution of energy usage in each dwelling which is ranged in between 28 % up to 46 % from the overall electric usage. The relationship between the electric energy usage and the outdoor air temperature is more remarkable during the night time as compared to the hot daytime. This is due to the different nature of occupant's behaviour in both conditions. These time series results are very beneficial in developing the forecast model of energy usage behaviour and energy saving planning for reducing the carbon dioxide (CO_2) emission in Malaysia.

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