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A study on energy consumption of a resort located in the east coast of Malaysia

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ABSTRACT

Rapid developments on tourism industry in Malaysian east coastal areas are expected to increase the electricity consumption. The situation worsens as the intermittent weather condition in that area also causes inconstancy on the electrical consumptions pattern. Thus conducting studies on electricity consumption are essential to ensure reliable and economic power generation in future. This paper intends to elaborate on the study conducted to estimate hourly energy consumption of a resort complex consisting of 34 chalets and a restaurant. A survey was performed to obtain variables such as number of occupants, chalets occupancy, chalets building material, restaurant operations as well as typical daily electricity consumption. The electrical energy consumption was evaluated in three different end- use categories namely air conditioning, domestic water heating and electrical appliances for both chalets and restaurant. Various estimation methods were implemented in order to segregate the energy consumption into respective end use group. The results show that the average electricity consumption from November to January is lower compared to consumption in March to October due to monsoon season. Furthermore, 40% of electricity consumption was contributed by air conditioning usage in the chalets.

1. Introduction

Since the establishment of the Malaysian East Coast Economic Region (ECER) programme in 2007, rapid development on tourism infrastructures were observed (Bhuiyan et al., 2012). The development in east costal tourism industries is forecasted to increase the tourist arrivals to 30 million by 2020. The Global National Income (GNI) is also expected to rise up to RM2.6 billion as well as providing 69000 job opportunities in tourism cluster. The programme also creates opportunity in real estate development such as hotels, resorts, homestays as well as commercial buildings which improve the east coast economic growth. The boost in economy growth also expected to increase the electricity demand as the nation's previous trend shows increment in demand by a factor of 4 from the period 1990 to 2012.

In 2012, the Malaysian commercial sectors that includes public buildings and infrastructure such as hotels and resorts consumed up to 33% of total electricity consumption which is higher than residential buildings that consumed only 21% of the total electricity consumption. Hence, upgrading existing power plants timely in east coastal region would serve to be a sustainable step in providing continues electricity supply. In addition, intermittent energy demand during the monsoon seasons serves to be a challenge in obtaining economic power generations. In order to sustain the energy demand, an in depth understanding in energy consumption pattern especially on non-grid connected resorts or hotels are necessary to provide economical and reliable power generation. Furthermore, implementation of renewable energy schemes, cogeneration system or tri-generation system and zero energy building scheme in such remote resorts require in detail information on energy consumption for designing as well as sizing. The energy consumed by end-users are commonly evaluated in three different categories namely air conditioning (AC), domestic water heating (DWH) as well as electrical appliances and lighting (EL) (Swan and Ugursal, 2009).

There were few studies conducted to evaluate the energy consumption in Malaysian residential sectors. in (Saidur et al., 2007; Ivy-Yap and Bekhet, 2014). In commercial sectors, Saidur et al. (2010), had studied on end use energy consumption in a public hospital in Malaysia where the EL end use group shows the highest energy consumption. The study on energy consumption in a large scale hospital consisting of a nursing college were also presented by (Moghimi et al., 2014). In addition, there was also a study performed in Malaysia on energy consumption in an office building where the AC group shows the

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highest consumption with 57% of total annual energy consumption (Saidur, 2009).

However, there is no recent study focusing on energy consumption in hotels or resorts located in Malaysia. Furthermore, there is also an absence of studies on the variation of energy consumption based on end-use group conducted in the east coastal area in Malaysia. Hypothetically, as the east coastal area of Malaysia suffers northeast monsoon from November to February, the energy consumption during that period is expected to reduce as the number of tourist would be low. Thus, the objective of this study is to investigate a pattern on electrical energy consumption of a resort in east coast of Malaysia. The selected resort consists of 34 chalets and a restaurant. The energy consumption were estimated through data obtained through survey conducted in the resorts. The survey data were then interpreted as an input for several forecasting models to estimate hourly energy consumption based on end-use groups for a year.

2. Methodology

2.1. Targeted building

The Juara Mutiara Resort located at 2°47'41.9" N 104°12'11.5" E in Tioman Island was selected as the demand site for this study. The resort consists of 34 air conditioned chalets that are able to sustain 125 occupants per day. There is also a restaurant operating under the resort management located nearby the chalets that operates 15 hours daily. There are two different sizes of chalets available in the resort where each acquired a total area of 17m^2 and 14.9m^2 respectively. There are 27 types-A chalets which are designed to accommodate 4 occupants, whereas type-B chalets are only designed to accommodate 2 to 3 occupants. The chalet is built with wooden structure and the interior surface is layered with 5mm plywood. The slate is used as the roof material which is attached on a wooden slope frame and the ceiling are fabricated using gyp board.

Annually, the resort received more than 10,000 tourists including both foreigners and domestic tourist. In 2015, the resort had received 9570 occupants in 265 days of operation. The resort was not occupied for nearly 100 days due to adverse weather condition surrounding the island. A total number of 2560 chalet occupancy were recorded throughout the year as shown in Table 1.

The highest recorded tourists occupying the chalets were 2538 occupants in June with the total number of 690 chalets in operation throughout the month. The number of occupants and the number of chalets occupancy from November to February were low in which the lowest record was observed in November with only 28 occupant and 11 chalet occupancy respectively.This was due to the northeast monsoon season where extreme weather condition of rains and winds caused most of the transportation services to the island shut downed from November to February. This phenomenon also caused constraints to the power producer companies as some of the generators had to be operated at low partial load which further increases the running cost of the system. Currently, the electricity supply to the resort is obtained through mini plant of diesel generator installed by Tenaga National Berhad (TNB).

2.2. Data collection on weather condition

Identifying the weather condition on the resort surroundings is essential in order to obtain accurate estimation on the electricity consumption of the resort. The ambient temperature affect space cooling and electricity demand extend. On the other hand, solar irradiation also responsible for the necessity of space cooling as it affects the conduction and radiation of heat transfer penetrating into the building cooling space. Therefore, acquiring information of site solar irradiation and ambient temperature are essential in computing the energy consumption precisely.

2.3. Ambient temperature

The real time ambient temperature data were collected at 5 minutes interval through sensor with reading uncertainty of ±0.5^{o}C and averaged into hourly temperature data from January to December. Fig.1 display the monthly average ambient temperature where the highest temperature recorded was 38.8^{o}C that occurred in April, August and October respectively, whereas the minimum temperature recorded was 22.2^{o}C in June. The monthly mean temperature ranges from 26.0^{o}C to 30^{o}C in which the highest mean was recorded on July and the lowest on February

2.4. Solar irradiance

The real time data of global solar irradiation was logged for every 5 minute step from January to December. The instrument utilized for the data collection was a pyranometer with sensitivity ranging from of 5µV/Wm^{-2} to 20µV/Wm^{-2}. The global solar irradiation were then decoupled into diffuse and direct irradiation based on the model reported in (Azhari et al., 2012). The total monthly global, direct and diffuse solar irradiation is presented in Fig. 1 where March displays the highest solar insolation with 191.8kWh/m^2 per month. The solar insolation in February was the lowest which is only 100.6kWh/m^2.The peak global irradiation recorded 1121Wh/m^2 in November where the estimated highest direct radiation is 908.1 Wh/m^2. Decoupling the data on global radiation shows that the 59.2% diffuse radiation were receives annually. In summary, the site received a total of 1.87MWh/m^2 of solar insolation with 1.11MWh/m^2 was diffuse radiation and 0.77MWh/m^2 of direct radiation from January to December.

2.5. Estimating energy consumption

In this study, the resort electrical energy consumption is evaluated based on 3 different end-use groups as shown in Table 2. The type and number of appliance ownership were obtained though site visit survey. The proceeding subsections implied to elaborate on the method utilized to compute the electrical energy consumptions.

Table 1: Monthly number of occupants and number of chalet in operations

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Occupant	90	191	694	1432	1074	2538	681	873	1237	628	28	104
Chalet Occupancy	24	52	189	390	292	690	185	237	336	171	8	28

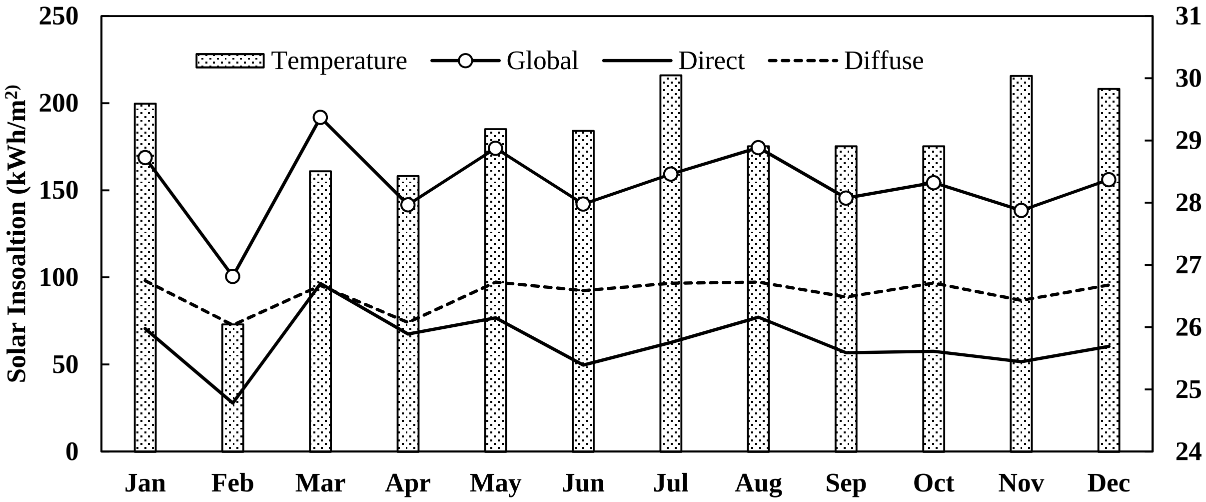

Fig. 1: Monthly average ambient temperature, global radiation, and direct radiation and diffuse radiation

Table 2: Type of end-use group and appliances

End-Use Group	Appliance	Unit
Electrical Appliances (EL)	Light	332
	TV Satellite Receiver	34
	Television	35
	Electrical Kettle	34
	Freezer	41
	Kitchen Appliance	11
	Washing Machine	2
Air Conditioning (AC)	Air conditioner	34
Water heating (DHW)	Water Heater	34

2.6. Water heating and electrical appliances

In order to determine the hourly DWH and EL electricity consumption in both chalets and restaurant, a survey was performed to identify the hourly average usage. Fig. 2 displays the electricity consumption of DWH, EL in chalets and EL in restaurant for 24 hour that was normalized into percentage basis. The percentage was obtained through normalizing the average electricity consumptions into hourly data that are obtained based on the survey.

In the case of chalets, the daily average electric consumption by EL obtained through the survey was 3.2kWh.Considering the normalized percentage in Fig. 2 and the average value of electric consumption in chalets, the electric consumption at any hour, E(t)[kWh] is calculated through Eq. 1 as shown below:

$$E(t) = NP(t) \times C \times n(t) \quad (1)$$

where *NP(t)*[%] is the normalized percentage at t[h] hour, *C*[kWh] is the average daily electric consumption and *n(t)* is the chalets or restaurant quantity operating at t[h].

On the other hand, the restaurant EL energy consumption was evaluated in two cases namely consumption during operating day and non-operating day. During operating day, daily, the restaurant consume an average of 89.6kWh of electrical energy. Referring to the normalized percentage for restaurant in Fig. 2, the hourly electric consumption was estimated though substituting the average daily consumption into Eq. 1. During non-operating day, the restaurant was assumed to consume 0.63kWh of electrical energy every hour. This was due to the operation of 7 refrigerators that are kept running for 24 hours a day. During idle operation the restaurant consumed 15.2kWh electrical energy daily.

Table 3 summarize the survey result on the hot water utilization in chalets. Based on survey, it can be deduced that a chalet consume 210 litres of hot water daily; the electric consumption of instant water heater at any hour. $E_{HW}(t)$ [kWh] calculated through Eq. 2, where $n(t)$ is the number of chalet operation at t [h] hour and $V(t)$ [m^3] is the volume of water consumed at t hour. The volume of water at t hour was obtained by multiplying the average volume of hot water consumption and the normalized percentage in Fig. 2 at t hour.

Table 3: Parameter and survey result on hot water usage

Parameter	Assumption
Flow rate, $\dot{v}$	7.5L/min
Density of Water, ρ	999.97kg/m^3
Specific Heat Capacity of Water, C_P	4.187kJ/kg. ^{o}C
Average Duration of shower	6 min/person
Water Outlet Temperature, T_{out}	60^{o}C
Ground Pipe Temperature, T_{in}	26^{o}C
Average Volume of Water	210L/ chalet

$$E_{HW}(t) = \frac{V(t)\rho \times C_p \times (T_{out} - T_{in}) \times n(t)}{6} \quad (2)$$

2.7. Air conditioning (A.C)

Estimating AC electric consumption requires consideration of the weather conditions as the cooling energy demand changes drastically with the ambient temperature and solar radiation. In this study, Radiant Time Series (RTS) method was utilized to calculate the hourly cooling load. In detail calculation of each heat gain which provide insight on the heat gain pattern is required in calculating the AC energy consumption, however, RTS method provide simplicity in computing thus reduce the computing time.

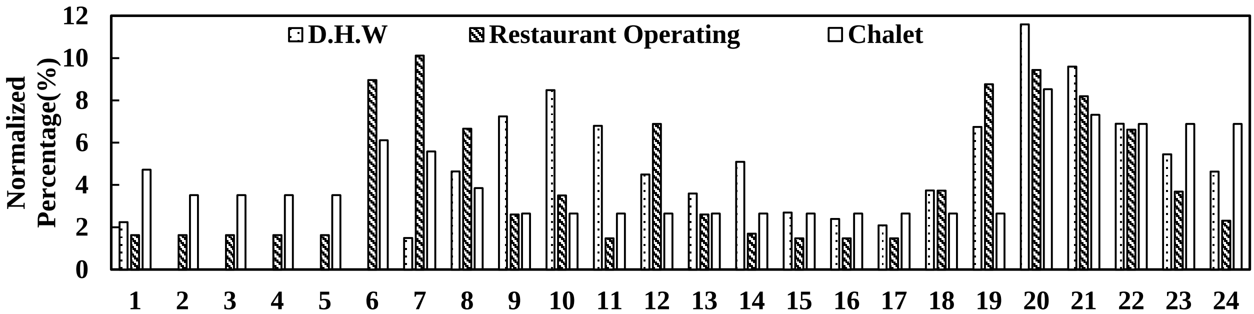

Fig. 2: The hourly normalized EL consumption (Restaurant and Chalet) and normalized volume of water (DWH)

In addition, the RTS method was also verified to be reliable validation as reported in (Iu, 2002). The calculation was performed for all the 34 chalets for 8670 hours as they have different orientation and in which the room design condition was assumed to be 23.4^{o}C and with 60% humidity. Other parameters such as dwelling envelops that include wall type, roof type and fenestration as well as the number of people and lightings were accounted in order to calculate the sensible and latent heat gain though the RTS method. The amount of electrical energy required by the air conditioner in a chalet to provide the cooling can be calculated by dividing the cooling load obtained in that hour by the COP of conventional AC which was assumed to be 3.0.

3. Result and discussion

The electrical energy consumption of AC, DWH and EL of respective restaurant and chalets were computed throughout 8670 hours in a year. The variability factor such as occupant number, chalets occupancy, restaurant operations and weather conditions were considered in the computing process. Figs. 3 and 4 display the monthly electrical consumption of respective AC, DHW, and EL of both restaurant and chalets throughout a year. The highest electrical energy consumed by the chalets was in June with 9555kWh. As shown in Table 1, the number of chalets operating in that month was the highest which consequently had led to high energy consumption. The electrical consumption by chalets from November to February was low with an average consumption of 410kWh per month as compared to the average electrical consumption from April to October which at 4087kWh per month. This is due to the weather condition on the east coast area of Malaysia as it is subjected to the northeast monsoon season.

This situation will result in low load factor on the energy consumption that subsequently w increases the operating cost and higher charge per kWh on the utility bills. Thus, proper dispatch strategy or distributed energy system with the capability of acquiring higher efficiency in partial performances would be economical in term of power generations technology option. Furthermore, load shaving through installing facilities such as mini-hydro dam, renewable energy system or storage systems such as battery and heat storage and smart grid transmissions would be favourable in such demand applications. The peak energy demand of the chalets was recorded in June with 39kW including the chalets and restaurant in operation.

In the case of electrical energy consumption based on the type of end-use group, it is obvious that air conditioning led the energy consumption by consuming energy ranging 56.2% up to 72.4% monthly. There are few factors that contribute to higher AC energy consumption than other end use group. Firstly, the type of dwelling material of the chalet where the walls and door were made of timber and having small gaps in between the wood resulting in to high infiltration. Secondly, there are no thermal insulation on the structures as well as with unfavourable orientation of some chalets increases the cooling load. The hot humid weather condition also contributes to higher AC electric consumption. On the other hand, DHW end-use group consume the lowest electrical energy among the end-use groups as the consumption ranges from 9.1% to 13.2% monthly. This is due to the fact that the average frequency of shower per day was only one shower per occupant. Furthermore, the survey results also indicate that the average duration per shower was only 6 minute the average volume of water consumed was also low.

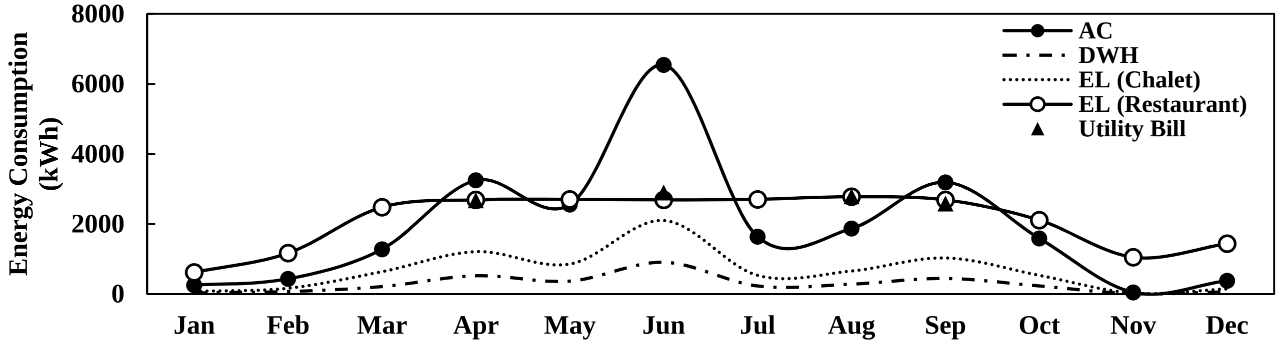

Fig. 3: The monthly electrical energy consumption of respective end-use group type

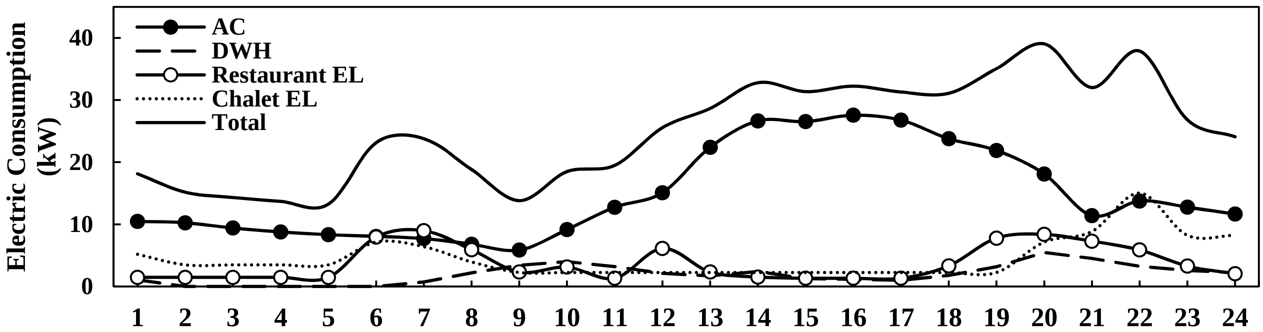

Fig. 4: The hourly electric consumption of end- use group on the peak day

Fig. 3 also shows the monthly electrical energy consumption of EL in the restaurant for a year. Due to lower number of operation from November to February, the energy consumption was low compared to the consumption from March to October where the average energy consumed is 2605kWh per month. However, considering the amount of energy consume in the restaurant during non-operating hours which may reach up to 450kWh per month, it is not energy conservative to operating up to 7 refrigerators daily.

In addition, Fig. 3 also shows several data of utility bills for comparison on the estimated energy consumption for restaurant. However only 4 utility bills were obtained as there are some missing bills and some bills were invalid for comparison purpose. Based on the comparison, there was slight deviation observed ranging from 0.3% to 7.0% when compared to the obtained utility bills. Hence, the comparison serves as a validation of estimated value and actual consumption data.

The Fig 4 displays the hourly electrical energy consumption on the peak day of each end-use group in both chalets and restaurant. The peak electrical energy consumption was recorded on 22 June at 8.00 P.M. There were 125 occupants and the restaurant as well as all the chalets was fully occupied on 22 June.

4. Conclusion

The study on energy consumption of 3 end-use categories which are air conditioning, domestic water heating and electrical appliance in both chalets and restaurant located in Tioman Island was conducted. The study shows that the electricity consumption in the chalets throughout a year was dominated by air conditioning as high as 70% of the total consumption. On the other hand, the restaurant consumed 40% from the total annual consumption due to the high number of refrigerators and freezer usage where during non-operating day it consumed approximately 15kWh of energy per day.

As the study was intended to assist the process of designing and developing sustainable energy system, it was seen that there are broad opportunities for a tri-generation system which utilize waste heat for space cooling. Furthermore, this study would also assist researches on designing system including Zero Net Energy Building, demand side management programs, and smart grid system in providing a sustainable solution especially to isolated resort.

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