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A study on the Correlation between the Energy Use and Occupancy Rate of Accommodation Buildings

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ABSTRACT: *Accommodation buildings are energy intensive among other commercial buildings, and it is considered as main producer of Green House Gases (GHG). On other hand, it is an important component of tourism industry in Japan. In the presented research, a study of energy performance of accommodation buildings in Kanto region- Japan carried out. The study depends on two national survey to run out this investigation. First, Database of Energy Consumption of Commercial Buildings (DECC), which is done by Japan Sustainable Building Consortium (JSBC). Second, Occupancy data of accommodation buildings, whichis conducted by Ministry of Land, Infrastructure, Transport and Tourism (MLIT). A number of factors that affect the energy use in accommodation buildings, such as building size, working hours, etc., were illustrated.*

A descriptive statistical analysis was carried out to find out the relation between occupancy rate and energy use of accommodation buildings in Kanto region-Japan. The relation between different energy forms and occupancy rate was investigated considering the outdoor temperature.As a result, the trend and correlation between energy use and occupancy was illustrated. The result of the study points out the controversial relation between energy use and occupancy rate of accommodation buildings in Kanto region-Japan.Since the considered values of R^2 *reported for energy consumption within period from Jun until October during the summer season, it is clear especially for electricity and city gas consumption, but it has low value rest of the year.*

Keywords*-Accommodation Buildings, DECC,Energy Efficiency, Occupancy Rate*

1. INTRODUCTION

The global contribution from buildings towards energy consumption, both residential and commercial sectors, has recentlybeen increasingto be in the range from 20% to 40% in developed countries[1].

The accommodation sectorisconsideredas the most energy intensive building categories[2][3][4][5][6]. Also it has a high environmental impact because of its large consuming of natural resources and producing

waste[6][7][8].Therefore, many countries declare variety of statutory requirements to reduce energy consumption of accommodation buildings without compromising the functionality[6]. In fact, the environmental impact of accommodation is obviously bigger than other commercial buildings with similar size. This is because of high energy and natural resources' consumption [9].

On the other hand, due to the multifunction character of accommodation sector, it requires different forms of energy such as electricity, diesel, and LPG. Typically, in cold climate zone electricity and gas are used as main sources of energy. While in sub-tropical and tropical zones, electricity is the major energy form that is consumed by accommodation facilities[10][11].

The energy performance of buildings is affected by various factors, such as ambient weather conditions, building' structure and characteristics, user behavior and the operation of sub-level components [12]. The energy consumption also is influenced by theenergy form, type and amount of available local resources, regulations and cost[3].

Intuitively, many would expect that energy consumption of accommodation sector is affected by its occupancy rate, but most studies have not proven yet a clear relation between energy consumption and occupancy rate.

The correlation between energy consumption and occupancy rate are not clearlyproportional because the occupancy are accounted as room occupants only. Other occupants or users of another facilities such as restaurant, conference halls and cafes are not included within occupancy calculations.Therefore,the relationship between the occupancy rate and energy consumption it is not clear due to the aforementioned unclear definition of occupancy [13][14][15].

Some of previous studies examined the correlation between energy consumption and occupancy rate, it shows a low value of the correlation coefficient R^2[3][11][13][16]. In contrast, other studies show a considerable correlation with high R^2[4][17][18][19][20].

In fact, each result of previous investigations has its own conditions of selected accommodation such as class, location, climate zone and other parameters. Therefore, they got different correlation method even in same country.

The study investigates the correlation between energy consumption of different energy forms and occupancy rate of accommodation buildings in Kanto region- Japan. It is the first study that tackles this issue in Japan.

2. JAPAN' ENERGY SECTOR AND JAPANESE'TOURISM SECTOR

2.1. Japan' energy sector

Japan imports 91.3 percent of its energy supply. After oil crises of the 1970s, Japan has taken actions to promote energy conservation, to find alternatives of petroleum, and secure supply of petroleum. However, after the Great East Japan Earthquake, the percentage of fossil fuels has been increasing, as a substitute for nuclear power as fuel for power generation.

Nowadays, despite of many actions for decreasing the dependence of energy imports Japan has beenconsidered as one of the most volatile countries in the world. Therefore, different organizations and government-bodies,public

institutions, economic agents and researchers concern about energy security[21].

Japan's final energy consumption has trended downward since fiscal 2005. In fiscal 2012, the total primary energy supply in Japan was 21,710 Petajoules. While energy consumption of the industrial sector has remained generally level, there were sharp increase in energy consumption of the commercial and residential sector and the transport sector. Comparing between commercial and residential sectors, the energy consumption of commercial sector arehigher than residential and has risen obviously recently. The residential and commercial sector consumes 33.5% of final energy consumption to be the second sector; the first sector is industry sector with 43.3 % according to annual report on national accounts[22].

2.2. Tourismsector in japan

Nowadays, tourist facilitiesprovide income and jobs;enhance harmony of foreign cultures, conservation of cultural and natural legacy and infrastructure investments[23]. Because of the previous benefits, the tourism becomes one of the most important social and economic activities in the world.

In Japan, the tourism sector contributes to the Japanese economy by 4.9% of nominal GDP and 6.1% of national employment according to Japan Tourism Agency. This direct effects show the importance of tourism industry in Japan as whole.

2.3. Accommodation buildings in Japan

In Japan, the increase of commercial sector' energy consumption is almost caused by the increase of the total floor area of commercial buildings[24].

In Japan, the accommodation sector are considered as one of the large energy consumers among commercial buildings about 3,421MJ/m^2 annual load[5]. As shown in Figure 1) it is the fourth sector among other commercial buildings after Department store, Office and health care buildings.

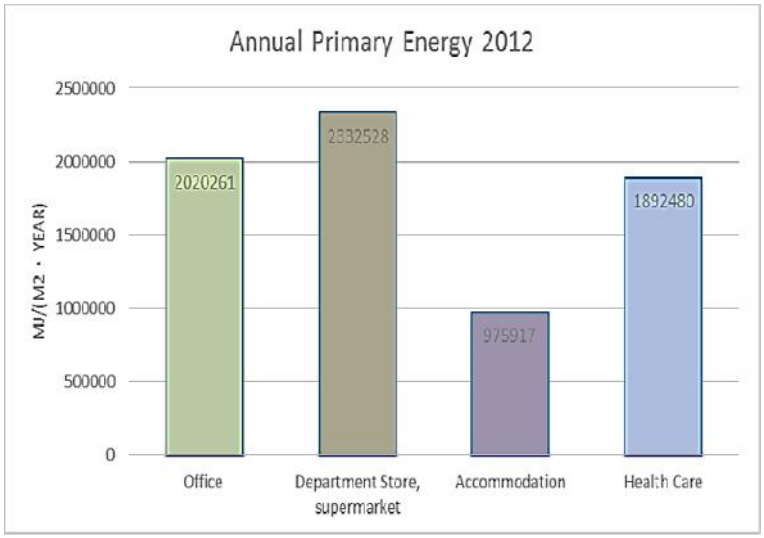

Figure 1: The primary energy of different commercial buildings categories in Japan 2012.

Japanese accommodation sector contains different categories such as the western style hotels, traditional inns, family-run guesthouses, pensions and membership resort clubs. Japanese-style inns (Ryokan) and guesthouses

decline continuously while the western style of hotels grow steadily in scale and number (JETRO, 2007).
Japanese accommodation sector represent two main trends, the modern trend as the western style hotels and traditional trend as Ryokan.

3. METHODS

3.1. Data acquisition

Many studies faced a lack of energy consumptiondata that reflects a significant limitation toward understanding the energy performance of building stuck[25].

Therefore, many methods are used to obtain the energy data of building sector such as standardreporting protocols, energy audits, specific questionnaires, online questionnaires and surveys[26][6].

The current study depends on national survey, which is managed by Japan Sustainable Building Consortium (JSBC). It is a national project to collect the database of energy consumption and water consumption of commercial buildings under the name of (DECC). This project launched from 2006 and it continues up to date with 40,000 samples as average including wide range of commercial buildings of all Japan.In 2011, following the great earthquake in Tohoku region, the data collected focused mainly on areas that were under an advisory to reduce power consumption. TheDECC allows users to access data for different commercial buildings categories. DECC's basic data, which do not include information that can identify specific buildings such as names and gross floor areas, can be downloaded from the DECC download URL[27].

Overnight trips survey is a statistical survey have been conducted on accommodation to reveal the status of overnight trips in Japan since 2007. The main Objective of this survey is to understand the nationwide scale of accommodation trips in Japan from 2004 until 2016. The survey database includes number of buildings, actual gust number and other related information on monthly base, quarter and annual base. This databaseis categorize based on different concepts and criteria such as the number of guests in each time period breakdown by prefecture, outside prefecture. Also the guest are classified as residence or foreigner and by nationality[28].

In this study, a selected data are used belong to certain years which are chosen because of a certain change of energy policy in Japan. For instance, a new goal to reduce the energy consumption in residential and commercial buildings was appointed in 2009. East great earthquake in Sendai region 2010 is an important event to compare the energy performance before and after this date, different categories of commercial buildings declare to reduce their energy consumption to meet the new change of national energy policy.

The DECC project contains various data related to physical and operation characters of building and energy consumption of different types of electricity and non-electricity sources. DECC project distributed the main eight regions of Japan into 12 categories and classified the commercial buildings into 24 categories according to its activity.

The overnight trips survey is conducted, continuously since 2007, on accommodation facilities inorder to clarify the actual conditions of overnight travels in Japan. It include wide range of accommodation facilities such as hotels, lodgments, resorts and Ryokan. Statistical information displaythe actual number of guest of

accommodationfacilities on national scale. In addition, it aims to survey different information related to Tourism such as number of inbound and outbound travelers, consumption trend for foreigner visiting Japan and other economic' indicators.

3.2. Area of study

This study is carried out on regional scale.It investigates the accommodation facilities of Kanto region which contains mainly Tokyo, Chiba and Kanagawa prefectures and some other cities. According to Japan Tourism Agency, Tokyo has the highest number of accommodation guests among other Japanese prefectures with 11430000 person (4th quarter of 2011).Furthermore, Kanto region has the highest number of surveyed buildings with high annual primary energy intensity among other regions. Moreover, the total floor area of surveyed accommodation facilities of Kanto region is more than 5 million meter square, which is the biggest floor area of surveyed accommodation facilities among other regions.

Beside the previous reasons, the selection of Kanto region as ahomogenous climate zonethat means to eliminate the weather correction regarding to geographic location.

3.3. Fuel mix and breakdown of energy source

The accommodation buildings are multi-function buildings with variety facilities, therefore different forms of energy are used to perform these functions.Beside to guest facilities, the location and size of accommodation building require variety forms of energy sources.

Electricity is the primary energy source to run air condition, lighting and other tasks. Natural gas (called city gas in Japan); itisused widely as better energytype to power heating equipment in accommodation facilities.

Propane gas(LPG) is consumed also in Japanese accommodation buildings especially in family accommodation's facilities; it is used mainly for heating, hot water supply and cooking. Last source of energy is oil fuel (diesel and kerosene) which is mainly used either for heating or to produce steam.

The study will breakdown the different types of energy to correlate the relation between energy use and occupancy rate separately. This procedure will enhance more deep understand of the expected relation between energy consumption and occupancy rate. Also will enhance more useful implementation of expected results in benchmarking energy performance of accommodation buildings.

3.4. Data analyzing

The multi-function of accommodation buildings and the diversity of their energy consumption produce large number of variables and parameters. Therefore, it is very difficult and complicated to quantify the energy performance in detail. These parameters are related to design, service and operational characters of buildings and they have different impact degree on primary energy use per unit. Because of the scope of the present research and the data resolution, certain parameters are selected to be examined.

There are many forms of statistical aspects to correlate the relation between two parameters such as Pearson correlation coefficient (R test)[18][13], which have similar equation of R^2. Both coefficients were used almost equally by researchers. In this paper, the relation between energy consumption and occupancy ratemeasured by value of R^2.

A correlation coefficient formula uses to correlate the relation between energy consumption and occupancy rate. The value of correlation coefficient $R^2$is shown in equation(1).

$$R^2 = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\sum(y-\bar{y})^2}} (1)$$

Where: R^2 correlation coefficient

xEnergy use$\bar{x}$ the average of energy use

yOccupancy rate$\bar{y}$ the average of occupancy rate

4. DESIGN AND OPERATIONAL FACTORS

As mentioned before, the character of accommodation facilitiesare affected by wide range of factors. In this study, some of design and operation factors are examined to point out the variation of energy consumption due to these parameters. In previous studies, each research investigates certain categories of variables up to his case study and scope of study. For instance, in case of individual building sub-system (air-condition-ventilation- lighting etc.) are reported[29][30]. Another studies focus on guest behavior and end-user[31].

4.1. Building size

In this paper, building' samplesareclassified within five categories according to their gross floor area. As shown in Table 1.

Table 1: Building floor categories (exclude indoor parking area)

Area Category	Minimum floor area m2	Maximum floor area m2
1	-	300
2	300	2,000
3	2,000	10,000
4	10,000	30,000
5	30,000	-

The size of building has essential impact on energy consumption. Certainly, the large building consumes more than the small one. Therefore, it is important to normalize the building's size before comparison process. Usually, the energy consumption are counted by Mega Joules unite per square meter or per room to consider the size or capacity of buildings. Figure (2) shows the annual primary energy intensity by gross floor area. It can be seen that the samples of category 3 (2,000m^2~10,000m^2) has the highest number of samples and high average of energy consumption comparing to larger area categories, the average of primary energy intensity of this category is 3000 MJ/m^2.year.

This category mainly includes the business hotels which offer simple facilities with acceptable price, these types of facilities are the preferable one for wide occupant in Japan more than high-class hotel or resorts.

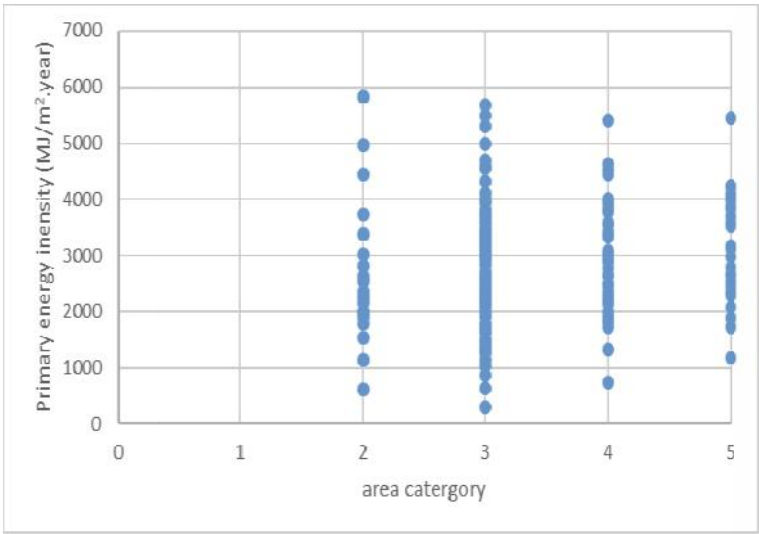

Figure 2: annual primary energy intensity and Area categories-Kanto region 2007.

The previous graph points out the importance to focus on the business and city hotels in Japan beside buildings of accommodation sector.

The number of stories is another indicator of building' size in vertical dimension. In figure (3), it figures the distribution of building' stories comparing with primary energy intensity in Kanto region 2007. The majority of surveyed buildings are medium high, the average stories level is about 5 to 15 levels.

Again, this figure confirms the most important category of accommodation buildings to be first priority.

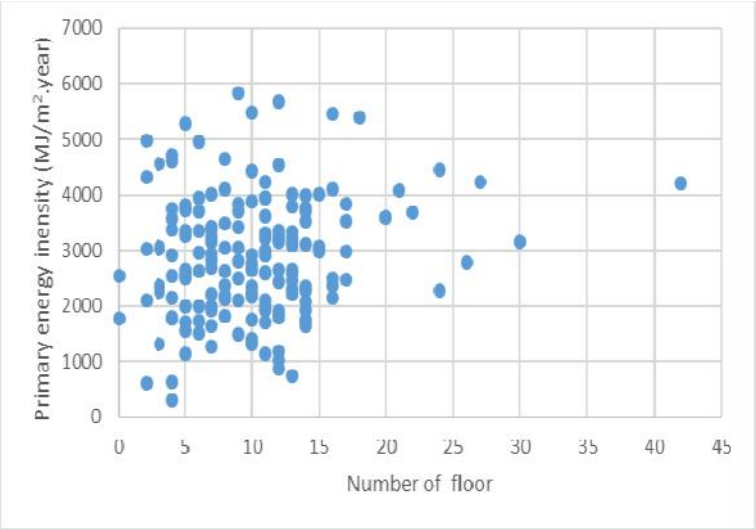

Figure 3: Annual primary energy intensity and number of stories-Kanto region 2007.

4.2. Construction date

The age of building is very important parameter to assess the energy performance; it is related to buildings capability to conserve energy and sub-systems efficiency. In addition to construction date, both of renovation and retrofit dates are necessary data to evaluate energy performance of buildings.

In this study, only the construction date will be used as reference of building's age.Generally, the surveyed samples are constructed in period between 1970~1990. As a general anticipation,the newest constructed buildings (after 2000) has less energy intensity than older one. On other hand,the constructed buildings during 90's has high primary energy intensity.

4.3. Daily operation hours

Incontestable, the high-energy use consumes in building which work 24 hours. Some buildings work less than 24 hours and have low energy use intensity than accommodation facilities with 24 hours of operation. Most of these low energy use building belong to traditional hotel or family-run guesthouses. The majority of accommodation buildings of national survey work 24 hours because of reduction of Ryokanbuildings' number[5]. Same argument can be applied on the cooling/heating periods during the entire year thatmajority of buildings operate the condition system for 12 month. Some of accommodation buildings have less than 12 month either as cooling or as heating periods especially in case of traditional hotel or family-run guesthouses.

5. RESULTS AND DISCUSSIONS

5.1. Electricity use

The usage electricityis as the main form of energy use in accommodation sector for air-conditioning, lighting, ventilation and other utilities. As shown in figure (3), the maximum electricity consumption occurs in August. During summer season, the highest temperature is recorded in August, also a long vacation period in Japan's calendar takes place in August. Therefore, the usage of air-condition system and other subsystems consume electricity atmaximum level.

It is clear in figure (4)that same maximum consumption points are reported in August for electricity consumption

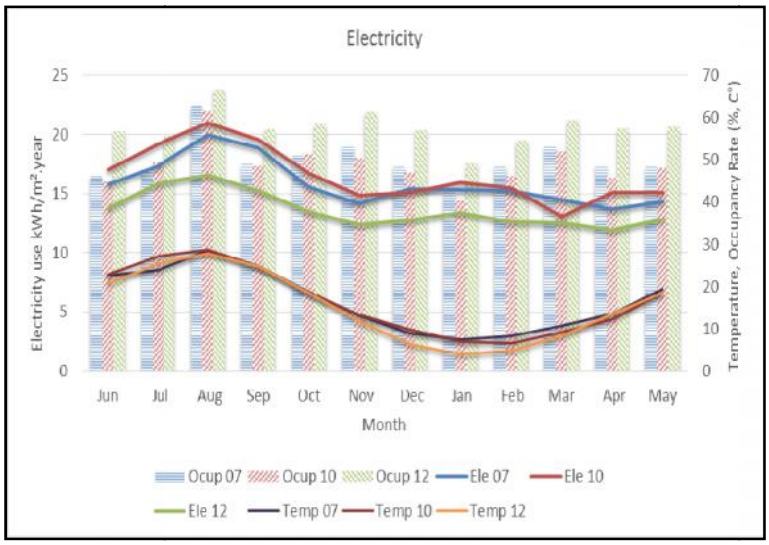

Figure 4: Electricity use intensity with Occupancy rate and Mean air temperature.

as19.95, 20.96, 16.57 Kw/m^2.year for 2007, 2010 and 2012 respectively.

In this study, the electricity consumption during the hot season is clearly correlated with temperatureR^2= 0.7 in

2007 data. However, when temperature decreases in cold periods the electricity consumption is increased but still lower than in hot season. This is because the other energy sources will be used for heating and other utilities.

The relation between occupancy rate and electricity use is more complicated than the correlation between Mean temperature and electricity use. Actually, the electricity consumption has two different correlations with occupancy rate during the whole year. The breaking down of entire year will enhance better understanding of consumption trend. It can be seen obviously in figure (4) that from June to October the electricity consumption has considered value of $R^2$with occupancy0.70, 0.68, 0.52 for 2007, 2010 and 2012 respectively.

On other hand, form figure (4) and R^2value, the period from November to May has no clear correlation with occupancy rate. That means it is difficult to confirm the correlation between occupancy and electricity use of used samples, either because of data resolution or because there is no correlation between them. However, the electricity use still correlated with mean air temperature within this period.

5.2. City gas use

Typically, city gas used in accommodation facilities to supply hot water, heating and cooking use. Figure (5) shows the trend of city gas usage. City gas is used broadly in cold season and during high occupancy rate. The R^2 value shows different correlation with occupancy rate during entire year. For instance, from June to October R^2= 0.71, 0.57, 0.57 for 2007, 2010 and 2012 respectively. These acceptable values reflect considerable correlation because of the high rate of occupant during hot season and summer vacation.

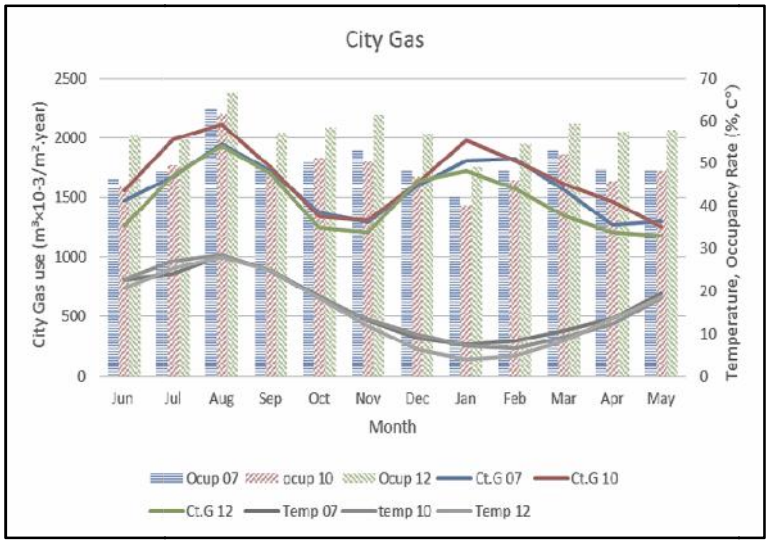

Figure 5: City gas use intensity with Occupancy rate and Mean air temperature.

Nevertheless,during cold period the correlation records is too low. The gas consumption intensity depends on of mean air temperature more than on occupancy rate.Especially in case of using hot water within accommodation facilities. The hot water usage will not be used at guest room only. Usually, some other facilities such as restaurant will have high use rate during cold weather. In these facilities, the use of hot water are not related directly to occupancy rate.

5.3. LPG use

LPG usage has low percentage comparing to city gas, only within small accommodation buildings such as family hotels or Ryokanstill use this energy form. The usage of propane gas is mainly for hot water supply, cooking and heating. The main difference between city gas and LPG is the Conversion factor of Primary Energy 45 MJ/m^3, 103.9 MJ/m^3 respectively. Also, the price of LPG is higher than city gas because of delivery cost.

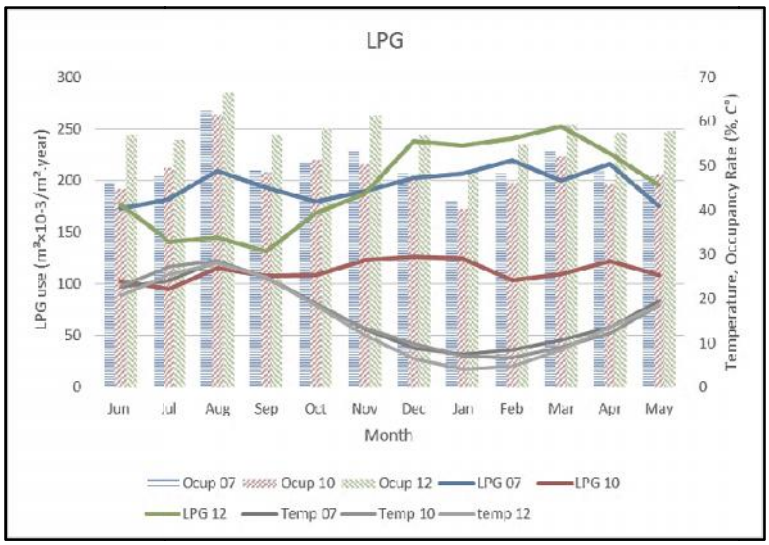

Figure 6: LPG use intensity with Occupancy rate and Mean air temperature.

The LPG trend is more complicated than city gas as shown in figure (6). It can be seen good value R^2= 0.89, 0.70 for 2007 and 2010 respectively within the period from June to October, but it has low value for 2012 in the same period. The same unclear values are observed for the second period from November to May for 2007, 2010 and 2012. These different values indicate low correlation or not clear correlation between LPG consumption and occupancy rate. As in case of city gas, LPGhas good correlation value with mean air temperature.

5.4. Oil (Thermal) use

The oil consumption in surveyed buildings includes diesel and kerosene. It can be noticed as shown in figure (7) that oil consumption increases significantly during cold weather due to use it to produce steam and other heat application.

Oil usage trend has high R^2= 0.90 and 0.89 for 2007 and 2010 respectively from June to October, but low correlationin 2012 in the same period. The high value presents the impact of high number of occupants who used to enjoy hot spring (Onsen) during summer vacation. Because of thermal usage of oil fuel in accommodation buildings, the consumption will be more related to temperature more than occupancy rate especially in cold weather. Therefore, we can recognize the high correlation between mean air temperature and occupancy rate. On other hand, it can been seen that there is no correlation between occupancy rate and oil consumption.

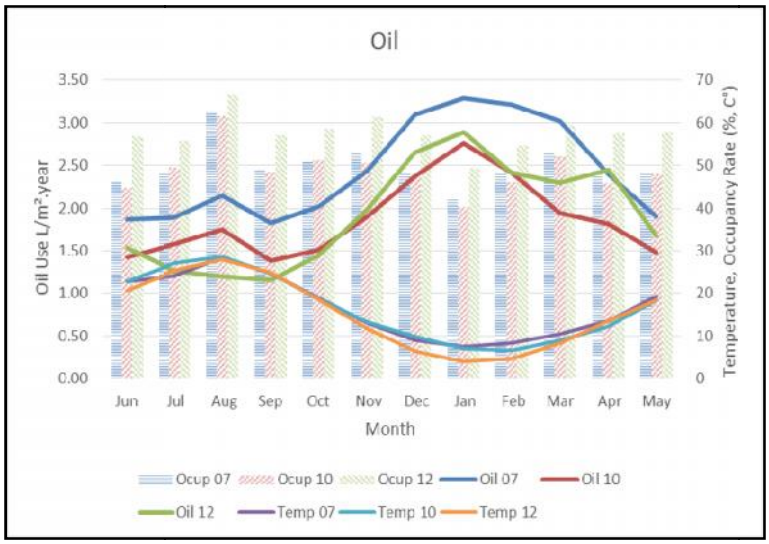

Figure 7: Oil use intensity with Occupancy rate and Mean air temperature.

5.5. Correlation coefficient

In this paragraph, the previous graphs have been transferred into table to point out R^2 values. The table (2) shows the difference value of R^2 with and without time breaking. Actually, the period break-down enhance better understanding for correlation between energy consumption and occupancy rate.

In table (2), the value of R^2 between electricityand occupancy rate has acceptable value from June t October 0.7, 0.68, 0.52 for 2007, 2010 and 20012 respectively. Similar values was reported for city gas consumption with occupancy rate 0.71, 0.57, 0.57 for 2007, 2010 and 2012 respectively.

Table 2: Correlation coefficient between energy use and occupancy.

	Correlation coefficient R^2								
	Occupancy rate % (2007)			Occupancy rate % (2010)			Occupancy rate % (2012)		
	Jun-Oct	Nov-May	Annual	Jun-Oct	Nov-May	Annual	Jun-Oct	Nov-May	Annual
Electricity	0.70	-	0.5	0.68	-	0.4	0.52	-	0.31
City Gas	0.71	-	0.2	0.57	-	0.2	0.57	-	-
LPG	0.89	-	0.2	0.70	-	-	-	-	-
Oil	0.90	-	-	0.89	-	-	-	-	-

Except the R^2 value between LPG and occupancy rate for 2012, R^2 has close value during the period from June to October. In opposite side, R^2 values was not clear or too low between different energy forms and occupancy rate from November to May. It can be seen the benefit of breaking down the time into cold and warm seasons to point out the accurate relation between energy forms and occupancy rate.

6. CONCLUSION

A descriptive statistical analysis through DECC and occupancy data in Kanto region for 2007, 2010 and 2012 points out the correlation between energy consumption of different energy forms with occupancy rate. It is clear that there is no clear relation between energy usage and occupancy rate of accommodation buildings during the

whole year, since the usage of energy sources has fluctuatedbehavior against the change of occupancy rate for the entire year.

Thecorrelation coefficient R^2 shows acceptable value during period from June to October especially in case of 2007 data. Nevertheless, the R^2 has various values within period from November until May. These values has either unclear correlation valueslike caseof electricity and Gas or low correlation value like case of LPG and Oil. Therefore, this paper empathizes the result of previous studies about the difficulty to prove the correlation between energy use and occupancy rate.However, it is important to consider the occupancy rate with the consumption of electricity and gas as effective variable in future assessment system such as benchmarking system.

The research's results are useful to evaluate the energy consumption of the accommodation buildings in Kanto area. For instance, the weight of the occupancy rate within assessment process or benchmarking system will not be high or equal to other effective factors. Other building's parameters, which have a clear impact on energy consumption such as building size, operation hours, construction date has bigger weight within evaluation process.

In future work, it is necessary to have more detailed data for selected buildings to find out the accurate relation between occupancy and energy consumption, such as number of employees, users of facilities and number of occupied rooms. In addition, it is more accurate to study same class buildings such as business hotel or resort facilities.

To sum up, this study unclear correlation between occupancy rate and energy consumption for all energy source and with entire annual operation period of the accommodation buildings in Kanto area. The study points outthe necessity to carry out detailed investigation to account the total users number of accommodation facilities including room's guest, restaurant's users and other public facilities, since accommodation buildings consists of three main zones guest room area, public area and service area. This consideration will enhance better understanding about the relation between energy consumption and using rate with accurate results.

7. Acknowledgements

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