ASSESSMENT OF ENERGY CONSUMPTION AS A PERFORMANCE INDEX IN HIGH-RISE BUILDINGS IN HANOI, VIETNAM

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Abstract
This research aims to at investigating the actual performance of high-rise office buildings in terms of the indoor environment and energy consumption. Data collection was based on the onsite measurement of five buildings in operation in Hanoi, Vietnam. The thermal environment, illuminance, CO_2 concentration, and energy consumption were the basic parameters analyzed as a fundamental step toward realizing and determining energy-efficient buildings. The current situation can be roughly was described; the most of methodology follow the western standard and there still be less data that show the actual situation under building operation documented. To analyze and evaluate, this research conducted measurement of indoor environment quality (IEQ) and energy consumption of high-rise office buildings between 2014 and 2015 in Hanoi. From the result, it is presented evident that the overall energy consumption and indoor environment of office buildings in Vietnam are not in a negative situation to compare favorably with international standards. However, it is also presented that there is a large high fluctuation in the thermal environment. The electricity consumption has strong relationship with outdoor temperature obviously and the peak consumption is observed in the summer. The consumption doesn't increase in winter despite indoor temperature show being lower than the standard comfort criteria-zone. This results in the lower energy consumption in the observed buildings due to the unique climate of Hanoi and inappropriate building operation mainly because of such as the insufficient operation of air conditioning systems and the air-tightness of building envelopes.

Keywords: actual performance, energy consumption, high-rise building, indoor environment, tropic.

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INTRODUCTION
Background
Energy source depletion and climate change have accelerated in recent years, making energy efficiency in the building sector is a focal issue. This is because energy consumption has a strong relationship within terms of economic growth and the quality of life. Hence, in several Asian countries where the construction of high-rise office buildings is increasing with rapid economic growth. There would therefore be a large need for energy saving potential mechanisms in the near future to cope with the corresponding change in the quality of life.

Vietnam, located in Southeast Asia, is currently experiencing a situation wherein in-surge in the construction of high-rise office buildings which have been constructed starting in the early 1990s. Within 20 years, the building sector was responsible for approximately 40 percent of the total primary energy consumption, and that portion is expected to increase significantly (Nguyen, 2012). Therefore, a reduction in the energy used by buildings is an important strategy in Vietnam (Nguyen, 2015).

With this high energy consciousness, the Vietnamese government is trying taking drastic measures such as expanding the number of green buildings (Decision 79/2006/QD-TTg, 2006). Further, and building standards regarding energy efficiency and the indoor environment, such as QCVN (EEBC, 2013; VBD, 2010) and TCVN (NDS, 2010), have been developed to solve these issues.

Although a building energy efficiency code is available in Vietnam, energy-efficiency provisions for buildings were first introduced in 2000 based on the research results of the fourth component of the Demand Side Management project with the cooperation of the Vietnamese Ministries of Industry and Construction and an international consulting company (APEC, 2016). Regulations from this code are applied to the building envelope, systems of outdoor and indoor lighting systems, and as well as air conditioning and ventilation with other power-consuming and energy-managing equipment. However, the technical requirements to be achieved in the code were just observed to be transferred from the international code (Joseph, Maithili, Yu, 2004). As there is no organization or agency that is officially responsible for data collection or maintenance of a database on energy efficiency, these activities have been developed separately by several organizations and with respect to specific projects. This is because the establishment and management of a database are significantly difficult in most countries, not only particularly in developing nations (Richard et al., 2014). Despite the fact that the characteristics of climate and culture are largely different from those in the Western environment, such regulations are based mostly on the standards of Western engineering. It could be said that these regulations lack the understanding of actual high-rise office buildings in Vietnam (APEC, 2009). In order to determine the appropriate building-energy-efficient policies for Vietnam, clarification of actual building performance is necessary (APEC, 2009).

Previous research and purpose of this research

For achieving high energy efficiency, several factors are expected to be verified regarding building performance. The typical data sources for monitoring systems are a compound of include the outdoor climate, building envelope, building equipment, operation and maintenance, occupants' characteristics, behavior, and indoor environmental conditions (IEA, 2013). An adequate indoor environment basically needs an air conditioning system which, although a comfortable indoor climate and impacts on energy consumption seem to be conflicting. Through the continuous onsite measurement of the indoor environment and energy consumption around the occupants, provide data for comprehensive suggestions would be ensue analysis associated with for the rational use of energy, good control of indoor air quality (IAQ), and correct operation of building systems.

Studies focusing on energy consumption and the indoor environment in the Asian tropics have been conducted by various researchers. For example, include Xiangfei et al (2012) who selected public buildings of a within the tropical area in China and conducted research on both aspects. In another study, Cheng (2014) conducted an investigation of energy consumption in high-performance buildings in the United States, Europe, China, and Japan. In addition, Jianjun et al (2014) compared building energy data between the United States and China. Of the total building energy used in four buildings, the heating, ventilation, and air conditioning (HVAC) data were handled without separating the heating and cooling. Even in developed counties and middle-income countries, the data collection of actual performance in office building has not yet been sufficiently done.

Research Studies on building energy consumption and the thermal environment in Vietnam tends to have been based on samples have drawn from selected residences and hospitals or some other types of building (Le, Hiroshi at al, 2009; Le & Hiroshi, 2010) as sample buildings. For instance, Trung & Kumar (2005) investigated 50 hotels to reveal examined the energy and water consumption in 50 hotels, and established benchmarks for the efficient use of resources.

Another feature of actual measurement surveys of office buildings in Vietnam is the limitation of the survey period. The research by similarly, Anh Tuan (2009) conducted combined actual measurements as well as with structured questionnaires, but the case study focused on only one building, and the survey length was typically just for a day of every two seasons. Although the work of Tokuda (2015) is based on a longer survey of almost spread over three months, but the data is only analyzed for the winter season only.

As mentioned above, the research focusing on the actual performance of high-rise buildings in Vietnam seems rather limited, and similarities would be observed in other developing countries as well. The reason for this is the difficulty in collecting actual onsite data [primary data] due to unpredictable user characteristics. More so, the because a national statistical database system for buildings [secondary data] is a developing process in those countries. In particular, it is not easy to measure actual data for high-rise office buildings even in developed countries due to stipulations of the occupants.

Therefore, the purpose of this research is to verify the actual performance of high-rise buildings in Hanoi, Vietnam. The parameters used in the study are culled from literature and include outdoor climate, indoor environment, and energy consumption. These are as a fundamental step for achieving assessing energy efficiency in tropical Asian countries in Asia.

METHODOLOGY

In order to evaluate the actual performance of high-rise office buildings, data was procured through actual measurement carried out this research selects on five purposely selected high-rise buildings and collects data by actual measurement in between 2014 and 2015. The analysis would then be centered on done in terms of the indoor environment variables and energy consumption.

Sample buildings

The five sample office buildings investigated are listed in Table 1. Buildings and designated A, B, C, D, and E - all, located in central Hanoi, were investigated. The number of floors above ground level ranged from the 19th to the 27th floor, and therefore which identified them as high-rise buildings. Most of the floors were used as office space, the basements were used for car parking, and the ground floors were as reception areas. All of the buildings were constructed between 2002 and 2013, and the main structural material was being concrete.

Table 1: Building outline

City			**Hanoi**		
Building name	**A**	**B**	**C**	**D**	**E**
Total stories	23	27	19	25	27
Gloss area [m2]	28000	22518	34640	61400	40000
Typical floor [m2]	981-1265	834	12245	2090	1520
Net floor area	823	644	940.2	1684	873 (1237)
Total space AC [m2]	18929	13910.4	17863.8	42100	21825
Celling height [m]	2.65	2.65	2.65	2.7	2.7
Investigated area [m2]	239	(507.6)	415	662+115, 542	392
Number of occupants	36	40	54	152	35
AC system	Individual	Central	Individual	Individual + central	Individual
Ownership	Private	Corporate	Corporate	Corporate	Government
Age (yrs)	2010	2009	2002	2013	2009
BMS system	yes	yes	yes	yes	yes
Façade	double glass	brick + single glass	brick + single glass	single glass	brick+ single glass
Electric capacity	2000+1600KVA	N/A	16000KVAx2	2500KVAx2	N/A
Occupants density	100%	90%	77%	65%	80%

Data collection

As this research focuses on the actual performance of high-rise office buildings, various measurements in terms of outdoor environment, indoor environment, and electric consumption were taken.

First, to understand the typical outdoor climate at this location, climate sensors were set up in a centrally located residential area in the city of Hanoi. The sensor measured once every minute and sent data to an Internet server automatically. The climatic data included barometric pressure, humidity, precipitation, temperature, and wind speed and direction.

Regarding the indoor environment, the indoor temperature, humidity, illuminance, and CO2 concentration were collected from September 2014 to September 2015, for all five buildings. The equipment illustrated in Table 2 measured the air temperature, humidity, and CO_2 density every five minutes and recorded the data in its internal memory for each sample floor space.

Table 2: Detail of instruments used for investigation measurement

Group	Description	Trade name	Parameter measured	Range
Indoor environment	Thermo CO2 meter	TR-76Ui	Co2 level Temperature	0 to 5000 ppm 0 to 45 ^{o}C
	Thermo UV	TR-74Ui	Temperature, Humidity, illuminance, UV	0 to 100 %RH
	Thermometer with black painted ball	RTR-52A	Globe temperature	-30 to 60 ^{o}C
Weather	Weather transmiter	WXT502	Barometric pressure, humidity, precipitation, temperature, and wind speed and direction.	
	Solar radiation, Solar illuminance	PCM-01N, ML-020S-O	Global net radiation, Global illuminance	
Electrical	Electricity consumption	WPC-PE1SP	Amperage, voltage	0.1-100A 600V

The indoor energy consumption including electricity for air conditioning (fan, AC indoor unit, and AC outdoor unit), lighting, and equipment (computer, laptop, photocopier, printer, etc.) were measured separately. Devices such as a power meter and clamp meter were installed in the technical rooms or electrical boxes of buildings A, B, and C, and the others. Gas air conditioning systems are unavailable for evaluation in Vietnam. All of the energy consumption and mechanical system controlling data were recorded and managed by a building automation system (BAS). Furthermore, the total building energy consumption data were obtained from an official report, which was issued by the building manager of Buildings D, C, and B.

Data analysis

Based on the above-mentioned data, this research did a comparison with national and international codes in order to present the actual office building performance for Hanoi. Additionally, individual building situations were compared.

The first step was to clarify ascertain the outdoor condition of Hanoi based on the with respect to temperature and humidity. Then the indoor comfort aspects environments including [temperature, humidity, lighting use, and CO_2 concentration] were measured and were compared for each of the seasons and also for each of the buildings. After these analyses, a comparison with national and international standards was done using the Vietnamese guidelines QCVN 09:2013/BXD (EEBC, 2013), QCVN 05:2008/BXD (VBC, 2008) TCVN 5687:2010 (NDS, 2010) and the United States ASHRAE code (American Society of Heating, Refrigerating and Air-Conditioning Engineers) respectively (ANSI/ASHRAE 55; 90.1; 62.1, 2013).

Another concern was the electrical energy consumption of each building. For an entire year of total energy use, intensity was compared with the typical building energy use in Vietnam (IFC, 2012). The monthly and daily averages were evaluated for three selected buildings, and twenty-four hours of detailed data for two buildings were recorded, including outdoor, indoor, and energy data.

RESULTS

Indoor environment

Description of outdoor climate

Figure 1 shows the average outdoor climate data as a monthly average of the temperature and relative humidity from May 2014 to May 2015. For each factor, the maximum temperature, average temperature, and minimum temperature increase from March according to the line chart transition, and the hottest season appears to be from May to September. May, the typical summer month, had an average temperature of 30.98°C. However, the winter from November to March of the following year had an average temperature of 17.6°C. Within a year of investigation, the hottest temperature in 2015 was approximately 1°C higher than that of 2014.

By contrast, the bar chart in Figure 1, which represents the relative humidity ratios for each month, shows the relative humidity was over 75% RH in the dry period in December.

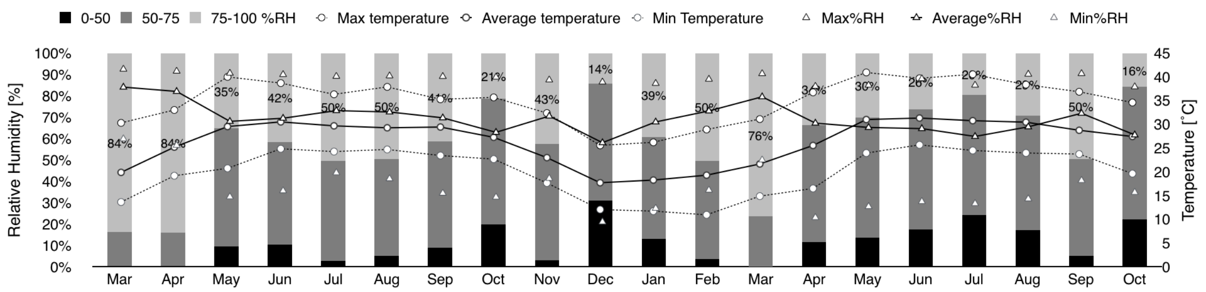

Figure 1: Outdoor temperature and relative humidity monthly transition in Hanoi (2104 March to 2015 October)

Comparison of frequency temperature levels

Figure 2 shows the monthly frequency recording of room temperature for five buildings in a full year, from September 2014 to September 2015, during the working hours of each day. There are fluctuations in temperature between each building. In particular, A and B have an approximately 2.5°C difference in February. By contrast, the difference in summer is only about 1°C, and the difference in room temperature between buildings in winter is much higher than it is in the summer period. This means that there is a wider difference between buildings in the winter season than in summer. To illustrate buttress this situation, the minimum temperature of the winter season was also very low (about 18°C to 20°C). The reason for this is that for Building C, the temperature of the air conditioning system was always set at about 18°C during the summer season, according to the building manager. Focusing on the figures from the lower to the upper quartiles of the box plot for each building, buildings C, D, and A were comparatively stable on the point of room temperature throughout the year.

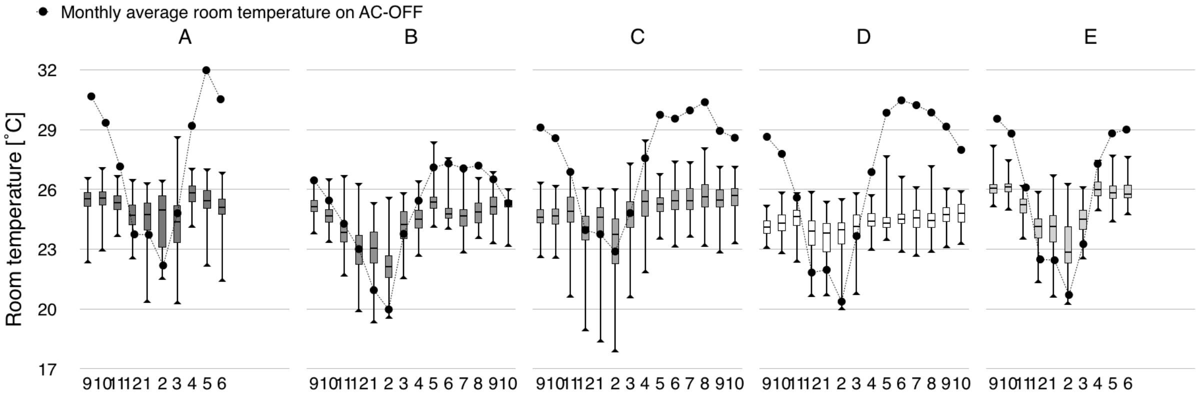

Figure 2: Mean monthly frequency of room temperature

The room average temperature fluctuated between 22°C and 26°C as the minimum and maximum temperatures. Compared to the international code "ANSI/ASHRAE Standards 62.1 and 62.2", which are recognized as standards for ventilation system design and acceptable IAQ (ANSI/ASHRAE 62.1, 2013), it is shown that these buildings in Hanoi satisfy the standards at the international level.

Similarly, as recommended in TCVN 5687:2010 (NDS, 2010) of the Vietnamese regulations, the room temperature in winter was indicated between 21°C and 23°C, and the summer temperature is between 23°C and 26°C. In a comparison with this code, the room average temperature in winter is higher than the recommended. In summer, however, it was stable at about 25°C to 26°C, which satisfied the requirement.

Comparison of frequency Humidity Ratios

Figure 3 shows the observed mean monthly frequency of absolute indoor-outdoor humidity ratios during working hours. The overall humidity ratio value approximately ranged between 5 g moisture/kg dry air to 18 g moister/kg dry air. Building C had a stable value of about 7 to 13 g moister/kg dry air, whereas the other buildings show wide variation from 5 to 18 g moister/kg dry air. The ASHRAE Standard 55, 2013 limits the humidity ratio at or to 12 g moister/kg dry air (0.012 kg moister/kg dry air). The observed humidity ratio often therefore exceeded the ideal range for thermal comfort.

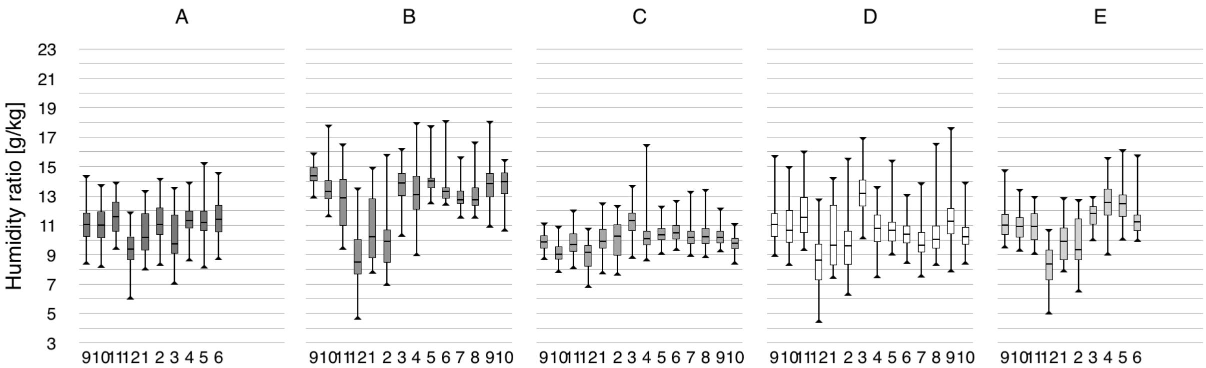

Figure 3. Monthly frequency of Room absolute humidity

In terms of relative humidity, the average values is ranged between 45% RH to 73%RH, and there are variabilities with large differences between the minimum and maximum values of room humidity (from 24% RH to 89%RH). Each building showed quite different averages of relative humidity: The RH for Building C was approximately 50% RH, and Building CE is approximately 70% RH.

Focusing on the seasons, the room indoor relative humidity in each building is appeared stable in summer and unstable in winter. In the summer period, the relative humidity is high, during in Building C was observed to be stable at all time. The relative humidity [RH] of comparison with the outdoor relative humidity, each room relative humidity was considerably less than the outdoor condition.

Going by compared to another international code, the most humidity levels should range are between 45% RH and 70% RH. Although only Building B showed a humidity of more than 70% RH, but generally most of the buildings were still within the comfort zone. However, when compared to regulation TCVN 5687:2010 of Vietnam (VBC, 2010), which the standards recommend a room relative humidity in winter and summer of 60% RH to 70%RH respectively. From this evidence, it can be seen that the actual situation of Vietnam showed a wide range humidity values matching with national and international codes.

Daily transitions of indoor illuminance

Figures 4 and 5 are line charts of the average daily transitions in indoor and outdoor illuminance in winter and summer. From each three-month period, this research selected a typical day and calculated the average hourly outdoor and indoor illuminance. The average outdoor illuminance value was about 45,000 lx on a sunny day in winter, compared with more than 50,000 lx in summer.

The average illuminance in each building is around 200 lx; Building E showed the highest value during these measurements. Comparing the winter and summer seasons, the indoor illuminance value in winter was higher than it was in summer, although the outdoor value was lower. It can be surmised that the reason for this is that window blinds tend to be fully or half opened in the winter season.

During office time, the outdoor illuminance slowly reached its peak value at noon and decreased until evening. However, indoor illuminance increased at office opening time and remained stable during working hours. There is weak relationship between external illuminance and the use of artificial lighting during working hours. The occupants always turn on the artificial lighting and close the inner blinds. From the above, it is presented that office buildings rely solely on artificial lighting during working hours.

The line chart also shows the lowest illuminance values between 12:00 and 13:00. This is probably because the occupants leave the buildings during lunch hour; or as habit of napping culture of Vietnam, a lunch break was founded in all most offices. Occupant's behaviors were often turn off lighting to take a nap after lunch, that explains why the indoor illuminance value shown the dual peaks in 24hrs while was trough lower 200 lx when outdoor illuminance is at peak value.

The peak value of illuminance is from between 350 lx and 550 lx for all buildings in all seasons. Most of the lighting environment is not very high, even during working hours. In terms of the Vietnamese guidelines, 300 lx is the lowest recommended value in QCVN09:2013/BXD (EEBC, 2013) or QCVN05:2008/BXD (VBC, 2008) for an office space. This shows that the actual performance of the buildings can be considered sufficient.

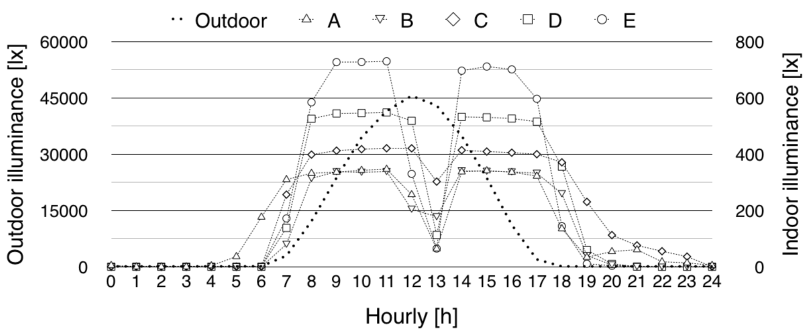

Figure 4: Comparison average indoor illuminance of Winter season

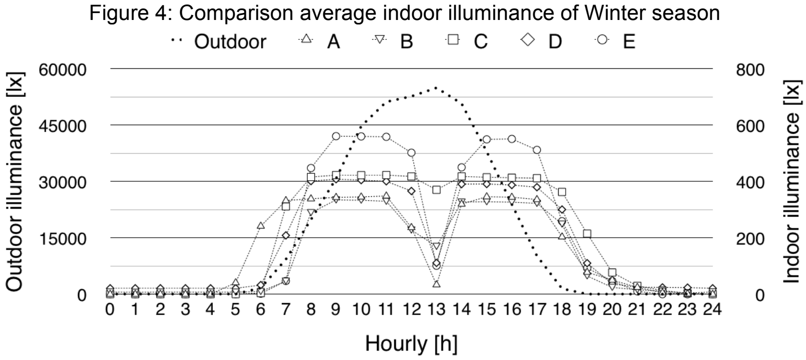

Figure 5: Comparison average indoor illuminance of Summer season

Daily transitions of indoor CO2 concentration

In this investigation, all of the buildings had an indoor environment with non-natural ventilation. The CO2 concentration in a closed area is mainly influenced by active ventilation, which is often part of an air-conditioning system. Elevated levels of CO2 may indicate that additional ventilation is required.

Figures 6 and 7 show that the CO2 concentration increases from the beginning of work time in all of the case studies for all during both winter and summer seasons. The value varied widely between 600 to 1300 ppm during working hours. Focusing on each of the buildings, Buildings C and A were always high.

However, the CO2 concentrations in the winter period were higher than in summer. This shows that the value for each building is different depending on the season. There may be many factors influencing the concentration of CO2 in the air space. The ventilation systems were not sufficient to recover fresh air into the space in winter; only Building D maintained the same value for the entire time.

ASHRAE Standard 62.1 recommends an indoor CO2 level not to exceed about 700 ppm above the outdoor ambient air, which is typically about 300 to 400 ppm. Regarding domestic codes for office space, the Vietnamese guidelines (EEBC, 2013; VBC, 2008) recommend less than 1000 ppm. Vietnamese buildings could have the potential to improve CO2 concentrations in the winter season based in the various standards.

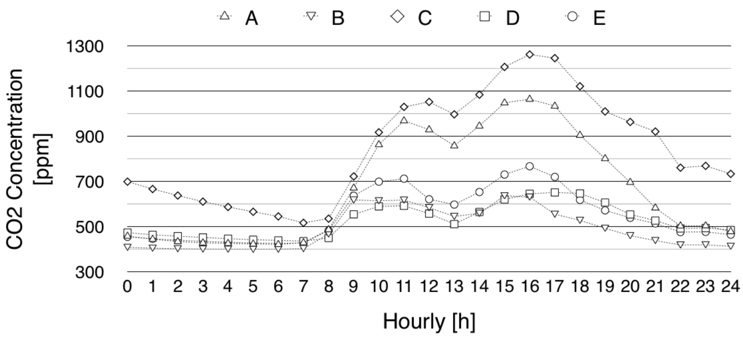

Figure 6: Comparison average CO2 concentration of Winter season

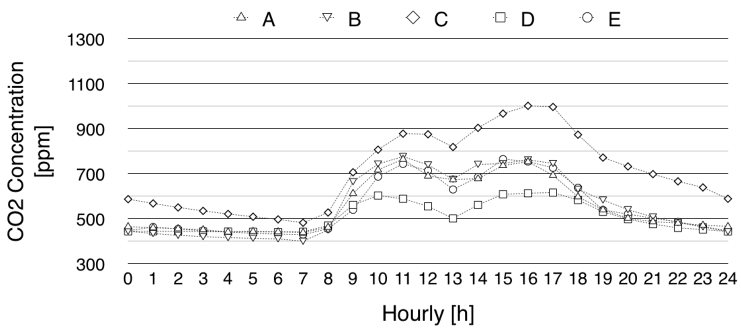

Figure 7: Comparison average CO2 concentration of Summer season

Electricity consumption

For the electricity consumption of office buildings, data for the whole year were collected in three buildings and compared on an annual and monthly basis. Since there was no gas consumption for space heating, because gas is not available in Vietnam, gas data were eliminated from collection in this study. The data is based on technical reports issued by the building manager. Values for Buildings C and B were reported at 8:00 a.m. each day, but values for Building D were reported only monthly.

As data collection depends on building reports, the data for some cases in some periods were unavailable, and the data ranges were uneven at the peaks of some periods. Building D was available from December 2014 to November 2015, Building C was available from January 2014 to November 2015, and Building B was available from January 2013 to November 2015.

The energy used each month was calculated using averages. To make the comparison easier, the time series on the horizontal axis was set as uniform from January to December using a mean average value. For Building D, the total area of 61,400 m2 was used for 65% of the gross floor area, and in December 2014, the report was missing data. Against a lack of data, data correction was done for electricity consumption on a total of 15% of the gross floor area. Buildings C and B used 77% and 90% of the gross floor area during the time reported.

Total annual energy consumption of annual transitions

Figure 8 shows the total electricity used in each buildings in one year based on technical reports. Building D was known to uses 160 kWh/m²/year, Building C, uses 115 kWh/m²/year, and Building B, uses 93 kWh/m²/year. Therefore, there is some variability between each of the buildings.

Table 3: EUI of Typical Office building (Source: Green building program in Vietnam, building survey report - Hanoi, 2012)

EUI [Kwh/m^2/yr]	**Hanoi**	**Da Nang**	**HCMC**	**Whole country**
Min	135	69	118	69
Max	211	140	231	231
Average	163	104	175	150

Comparing the total energy consumption with a typical Vietnamese office, the data from "2012 Green Building Program in Vietnam" is shown in Table 3. It includes the energy use intensity (EUI) of three typical office buildings in three main cities in Vietnam (Hanoi, Ho Chi Minh, and Da Nang) (IFC, 2012). In the process of issuing the green building code in Vietnam, an international organisation conducted a building survey, which includes the average numbers of covered 59 of buildings. The report also contained results from surveying approximately 100 buildings in the Northern of Vietnam, which was done by the Energy Conservation Center of Hanoi in 2009 and 2010. Comparing the annual electricity consumption with this research, the amounts for each building are similar to the annual consumption for a typical case in Hanoi, which from this reference is 163 kWh/m$^{2/}$year. The obtained research amounts values are also similar to those for Building D.

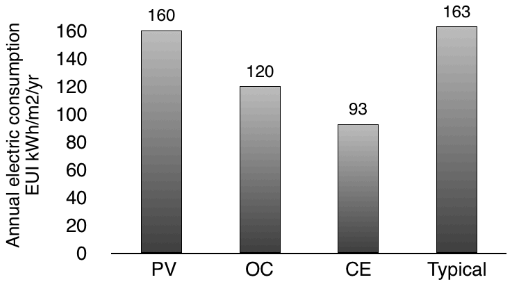

Figure 8: Annual electricity consumption comparison of case study building against typical office building in Hanoi

Figure 9 is a monthly comparison of the total electricity consumption for three buildings. It is clear that the three buildings differ widely in total electricity consumption from month to month, and the discrepancy is much larger in winter than in summer. Buildings B and C consume less energy in one year than Building D, which is always at relatively high level.

To determine the differences between the three cases, several factors may were considered. First, the indoor space temperature set point for cooling for Buildings D and B was 25°C-27°C, whereas that for Building C was 18°C. Furthermore, Building D's indoor ceiling space was 5 cm higher than the others. In terms of facade, Buildings B and C used a similar facade with 50% glass area, whereas Building D used 100% glass. This infers that an all-glass facade may perform less efficiently than one with a half-glass area.

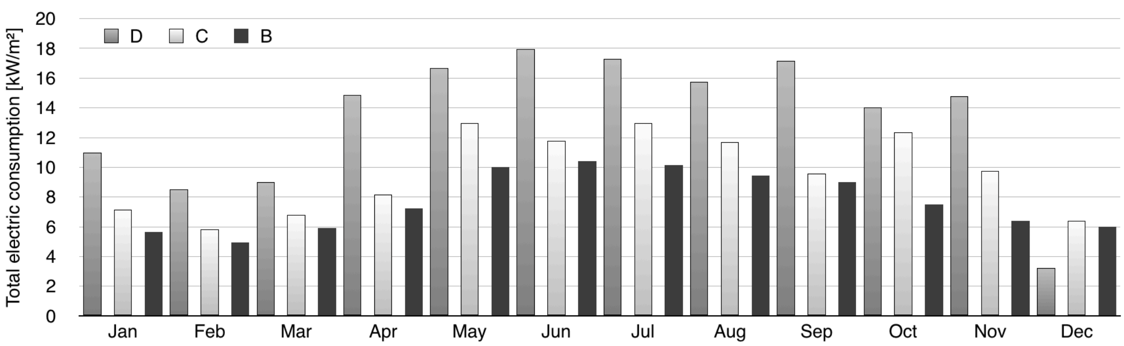

Figure 9: Monthly comparison of total electricity consumption

Typical monthly floor energy consumption by measurement

After an overview of the total annual electricity consumption, it is imperative to go further, into analyze the variably on monthly data basis. The data for three buildings were selected over the same time frame. Figure 10 shows the total monthly electricity consumption in a typical floor of three average buildings versus against the outdoor temperature. As can be seen, the month-to-month total electricity consumption varied considerably. In this bar chart, electricity included AC, lighting, and slot-socket equipment. It is clear that total energy consumption in summer was much greater more than in winter. Moreover, the outdoor temperature describes a similar shape to energy consumption.

In terms of heating, ventilation and air-conditioning, Building D uses a centralized system from the 1st to 23rd floors and a decentralized system from the 24th to 26th floors. Building B uses centralized system, whereas Building C uses an individual system. From the evidence above, the monthly change in total electricity consumption is considered mainly due to the changes in electricity consumption by heating, ventilation and air-conditioning. The value of the AC's outdoor unit electricity consumption in winter is lower than others, such as lighting, which usually uses less energy in office buildings. It can be also seen that the heating, ventilation and air-conditioning has a large decreased in consumption during this period, and the mean indoor temperature does not change much.

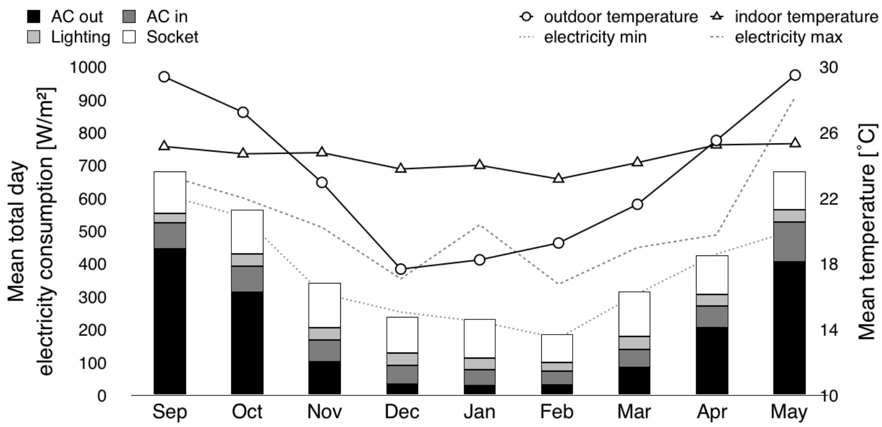

Figure 10: Monthly comparison of temperature and average day of electricity consumption

Daily average transition consumption in winter and summer

The next is a deep analysis to grasp the indoor environment related to the electrical equipment in an office space. Figures 11 and 12 show the daily average transition consumption in winter and summer for each of the three buildings. The value of socket electricity consumed is ranged between 110 and 136 W/m^2 /day in each month, and the value of lighting electricity is between 28 and 39W/m^2/day in each mouth. Each figure shows a similar value, approximately 35 W/m^2 in two seasons.

The value of electricity consumption for the indoor AC unit was 42.5 W/m^2/day during winter season and 120W/m^2/day during the summer season. The value of electricity consumption for the outdoor AC unit was 30 W/m^2/day during the winter season and 430 W/m^2/day during the summer season. As can be seen, the percentage of energy use is quite different in each season. Heating, ventilation and air-conditioning system in winter is constituted 38% of the total electricity use, whereas in summer it was 78% of the total.

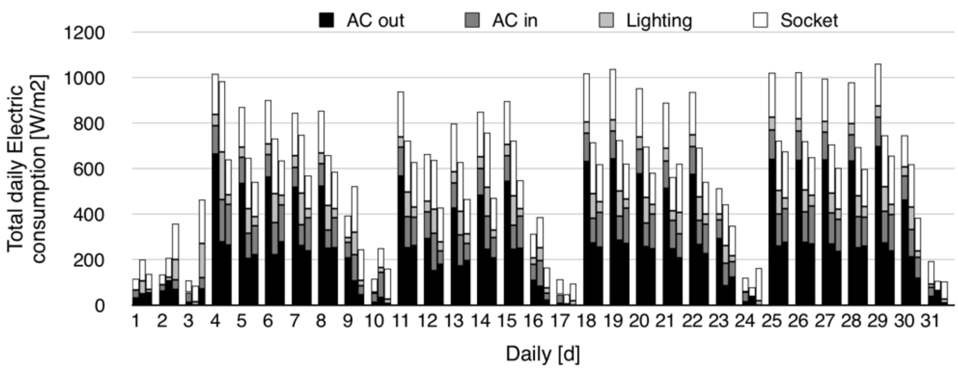

Figure 11: Electricity consumption on typical Summer month (May/2015)

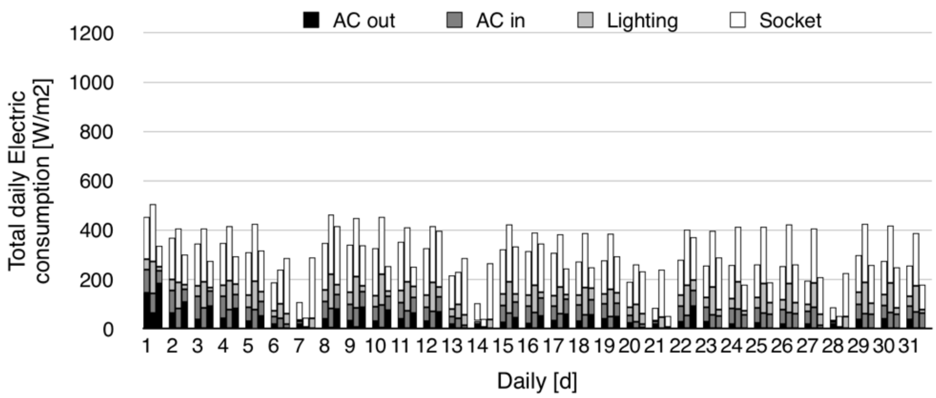

Figure 12: Electricity consumption on typical Winter month (DEC/2014)

Electric uses intensity

This section picks up the two building cases. To make the comparison easier, typical days were selected based on similar outdoor conditions with sunny days during the work week. A typical day in winter was selected by the lowest temperatures, which were between 11.9°C and 19°C in December. In summer, the hottest day was in May, with temperatures between 29° C and 42° C.

Figures 13-16 show the average hourly energy consumption and power density. The consumption of Building C was estimated at 48.3 W/m^2 (62.1W/m^2 in peak time), and Building A is 69.3W/m^2 (87W/m^2 in peak time). Compared with the Vietnamese standard QCVN09:2013/BXQ (EEBC, 2013), the mandatory total power density requirement for this type of office space is 75W/m^2. It can be seen that the actual building energy consumption is sufficient when compares with the Vietnamese standard.

In order to identify the energy uses of each type of equipment, the factors of lighting, socket, and AC are explained. The lighting power density of a building is equal to the total lighting output of the building divided by the total occupied area. In both winter and summer, the lighting power density of buildings C and A are between 2.9 and 3.4 W/m2, which is lower than that regulated in QCVN 09:2013/BXD (EEBC, 2013) (11 W/m2); However, ASHRAE 90.1 2013 shows that the lighting power density is recommended to be below 8.82 W/m2 (0.82 W/ft2). From the above, office building energy consumption in Vietnam is absolutely lower than each of the standards, as Figures 4 and 5 show the average illuminance reaching only 350 to 550 lx.

In terms of socket-slot, there were some variabilities in the electricity consumption for each season. This study did not include statistics for occupants during the measurements. The two companies in this study were a contractor and a project manager. This may be why the number of occupants is invisible at year end, as is often seen in Hanoi. Although the office equipments of the buildings were mixed, this research included server data. During the night-time, various computers were left on or in standby mode for various reasons. Table 4 shows comparison of survey data with the building code of Vietnam and ASHRAE standard in term of lighting and socket-slot.

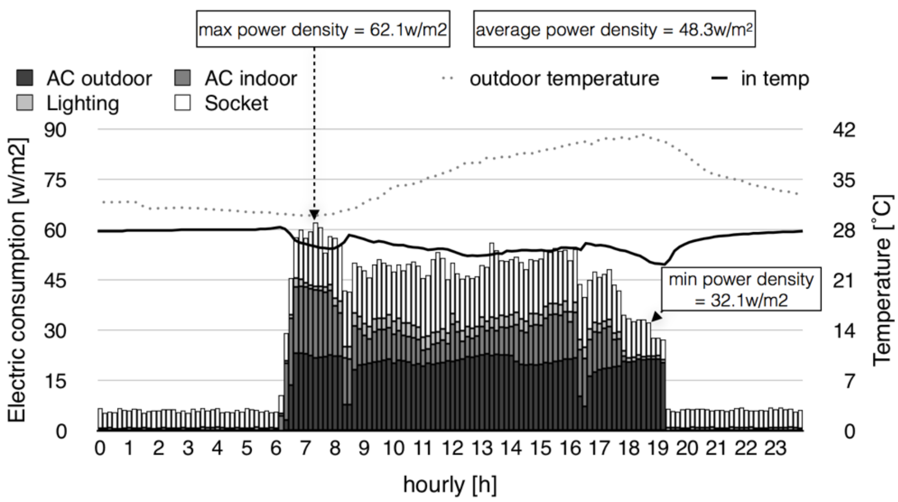

Figure 13: Building C electricity consumption power density on typical hot day

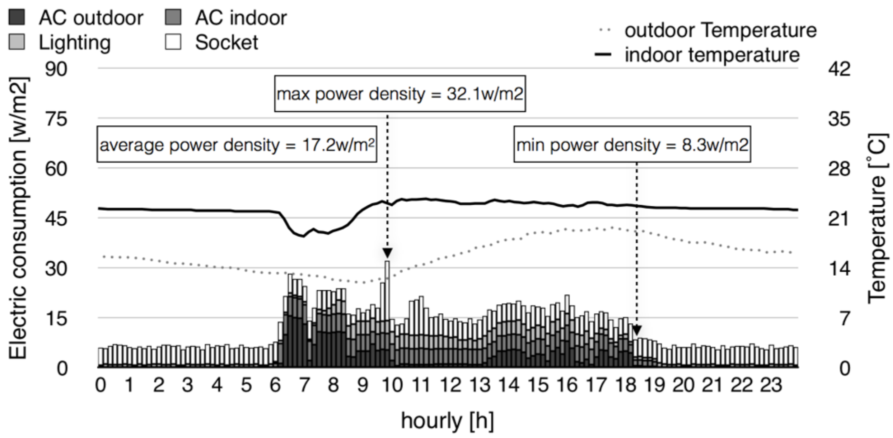

Figure 14: Building C electricity consumption power density on typical cold day

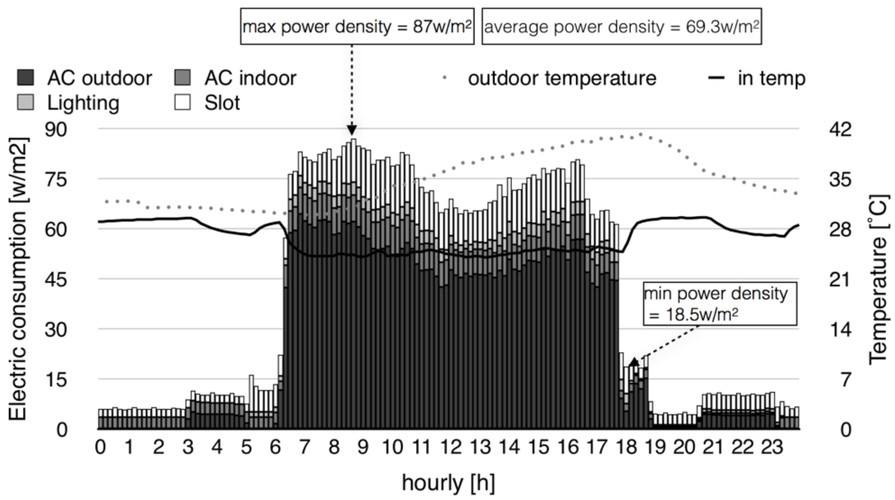

Figure 15: Building A electricity consumption power density on typical hot day

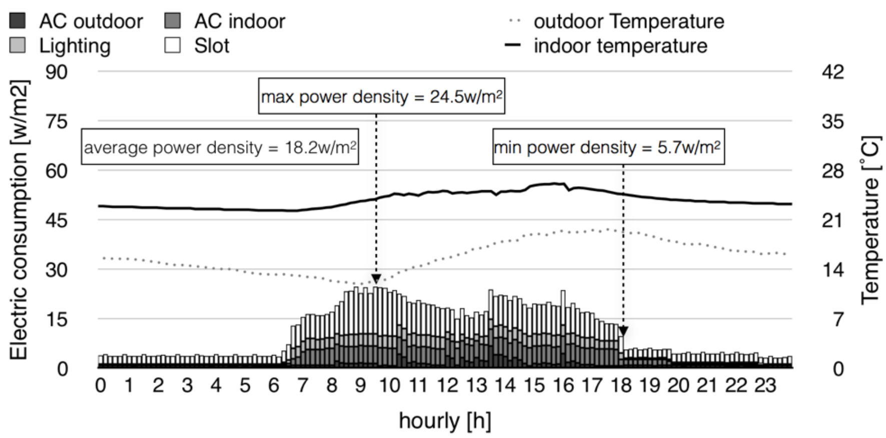

Figure 16: Building A electricity consumption power density on typical cold day

For the winter season, HVAC electricity consumption decreased to a very low level. Most of the times, only the AC indoor unit and fans were working purposely to reduce stale air. Meanwhile, Building C had a cooling load in winter. Figure 14 shows the room temperature reduction to 19°C from 22°C. This means that the building manager, could be 19°C set point temperature in the winter season.

However, comparing the two seasons, the indoor temperature was reduced by 5º C to 16°C during working hours in summer, whereas it was reduced by 5°C to 12°C in winter. From these results, it is clear that in terms of AC working time, even when the heating system is not working, the room temperature is still considered acceptable.

DISCUSSION

Throughout several investigations of office high-rise buildings in Hanoi, the outdoor and indoor environments and energy consumption specifications were similar to actual onsite data. Research is necessary in order to develop suitable tools and methods for the simultaneous analysis of both energy efficiency and IAQ. Therefore, this work examined the impact of possible energy saving measures on IAQ and suggests that same be discussed before their eventual adoption, and, if unacceptable, these measures should be avoided (ECA, 1996). This was attempts achieved in relation to the to analyze a comprehensive situation through a combination of various factors for energy efficiency.

Energy use and indoor environment

First, as a discussion of the comparison between seasons, summer was shown to a general condition that have high outdoor temperatures, moderate indoor temperatures, and high use of energy. However, winter showed lower numbers values for the indoor thermal environment along with the outdoor.

In the winter period, a reduction of air exchange rates to save energy was attributed to result in poor IAQ. The aggregated analysis of CO2 levels, indoor thermal performance, varying humidity ratios with outdoor conditions, and especially performance significantly reduced the electricity consumption of air conditioning systems in winter. The energy sled to significantly reduced indoor environmental quality. In the case of Building B, temperature and humidity exceeded the allowable limits in the winter period. Almost in all of cases, the CO2 concentrations in the office spaces in winter were higher than in summer.

Meanwhile, energy use in winter was quite low despite the low indoor thermal environment. This means that AC heating systems might not work effectively in the winter season, hence an increase in energy consumption.

In summer, the environmental quality in the offices significantly improved, most of the buildings had a stable temperature and humidity, and the average concentration of CO2 was reduced more than in winter, due to ventilation system usage. This also entailed an enormous increase in the use of electrical energy in summer. In terms of lighting, natural light was not utilized, although it is often seen as a source of summer energy in Asia. It also impacted significantly on energy saving issues.

Building database of total energy consumption

For total energy consumption, the energy benchmarking of office buildings has always been difficult. The reason for this is the limited number of buildings for which the actual status empirical data might reflect the regulations despite the importance of a database to assess energy efficiency. This study has investigated total energy consumption by actual measurement in a long period survey, and there was variability even in when only five buildings were sampled. It is suggested that a further number of surveys must be undertaken for the establishment of a building performance database in Vietnam. As energy efficiency needs to be considered and studied to adapt to outdoor environmental conditions, such comprehensive investigation would be required for an enormous number of building as a database. Furthermore, the major setback such as the absence of a database is commonly seen in other developing countries, where they must be established and accessed for academic and practical purposes in the near future.

Management and operation of buildings

Environmental quality management and the control of energy need to be carried out simultaneously, especially for the management and operation of buildings. In the case of Building C, the cooling mode setting was 18°C in winter, when the indoor temperature was 22°C. A building management operated air-conditioning system is not reasonable for one or two hours in the morning. This research indicates that there is inefficiency due to the energy use habits of building managers. In the near future, building energy monitoring systems, periodic inspections, and data collection of time series must be considered.

Building code

Another discussion is the comparison of actual performance with the national and international codes. Although there is a Vietnamese code regulating these factors, the actual performance of the thermal environment, illuminance, CO_2 concentration, and individual building energy use satisfy Vietnam's own national code and other international codes such as ASHRAE. It is presented that Vietnam office buildings are therefore not in a negative situation even when compared with international standards.

However, it is also presented that the buildings for which surveys were conducted showed non-uniform results. Moreover, especially because the thermal environment was not stable, energy consumption was expected to increase. The range of provided by the national codes would need to be revised in the future after collecting a sufficient number of case studies on actual building performance. Through that revision, benchmarks would be clear based on actual performance, not just simulations.

CONCLUSIONS

This research focused on the actual performance of office buildings in Hanoi, Vietnam and concluded as a result, it is presented that the actual performance of office buildings is not in a negative situation in irrespective of season, compared with various standards. However, there was a significant large variability in comparison with international and national codes. In the near future, additional detailed research would be needed in order to suggest the energy effectiveness of buildings in Vietnam. The research is summarized as follows.

Actual indoor environment

The thermal environment, illuminance, and CO2 level of each building are within the minimum and maximum recommendations of standard criteria in spite of a variability of the thermal environment, illuminance and CO2 for each building in Hanoi. The indoor thermal environmental conditions are unstable although with heating, ventilation and air-conditioning system control.

Actual energy consumption

This results in the lower energy consumption in the observed buildings due to unique climate of Hanoi and inappropriate building operation. The energy consumption has strong relationship with outdoor temperature obviously and the peak consumption is observed in the summer, an air-conditioning system reduces the indoor temperature effectively. In winter, the consumption does not increase despite indoor temperature show lower than the comfort criteria. Control, maintenance, and management procedures are essential, and strategies should be developed.

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