DEVELOPMENT OF SPECIFIC ENERGY CONSUMPTION PROFILE FOR TYPICAL BUILDINGS IN VIETNAM

XÂY DỰNG ĐẶC TÍNH TIÊU THỤ NĂNG LƯỢNG MỘT SỐ CÔNG TRÌNH XÂY DỰNG TẠI VIỆT NAM

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ABSTRACT

The economic growth in Vietnam has enjoyed a sustained strong performance in recent years. Similarly to the economic growth, the building sector in Vietnam has enjoyed a sustained development, especially regarding the construction of commercial and high-rise residential buildings. Such buildings are usually responsible for important electricity consumption. For evaluating energy performance of building overall, the specific energy consumption (SEC) profile is used to describe the energy consumption of all (or part of) energy consuming systems (HVAC, lighting, water heating, cooking, electrical appliance, etc.) per area over a specific period. It must be linked to a specific type of building, under a defined climate zone. In this paper, building energy consumption data is gathered from building energy surveys conducted by Ministry of Construction and international institutions (USAID, IFC…). Each collected database or information is quantitatively and qualitatively evaluated to provide SEC profile for identifying any potential correlation in between energy consumption figures and climate zones and/or any other relevant parameters.

Keywords: *SEC, building energy consumption, building energy survey, data analysis.*

TÓM TẮT

Trong những năm gần đây, tăng trưởng kinh tế Việt Nam ngày càng một ổn định và bền vững. Đồng hành với tăng trưởng kinh tế, lĩnh vực xây dựng ở Việt Nam cũng có sự tăng trưởng nhanh chóng, đặc biệt trong xây dựng các công trình thương mại và nhà ở cao tầng, dẫn tới tiêu thụ điện năng rất lớn. Để đánh giá hiệu suất năng lượng của tổng thể tòa nhà, đường đặc tính tiêu thụ năng lượng (SEC) được sử dụng để mô tả mức tiêu thụ năng lượng của tất cả (hoặc một phần) hệ thống tiêu thụ năng lượng (HVAC, chiếu sáng, đun nước, nấu ăn, thiết bị điện,...) trong một khoảng thời gian cụ thể. Ngoài ra, SEC cũng liên hệ với loại hình công trình, hay điều khiện khí hậu cụ thể. Trong bài báo này, các dữ liệu tiêu thụ năng lượng được thu thập từ điều tra tiêu thụ năng lượng công trình xây dựng do Bộ Xây dựng và các tổ chức quốc tế (USAID, IFC…) thực hiện. Cơ sở dữ liệu và thông tin thu thập được được đánh giá và phân tích để xây dựng đường đặc tính tiêu thụ năng lượng. Từ đó xác định mối tương quan giữa các tiêu thụ năng lượng với vùng khí hậu hoặc các tham số liên quan khác.

Từ khóa: *SEC, tiêu thụ năng lượng tòa nhà, khảo sát năng lượng tòa nhà, phân tích dữ liệu.*

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1. INTRODUCTION

The economic growth in Vietnam has enjoyed a sustained strong performance in recent years. The economic growth goes hand-in-hand with an increase of the energy and more specifically the electricity consumption. Electricity in Vietnam mostly comes from the use of non-renewable energies responsible for significant GHGs emissions. Similarly to the economic growth, the building sector in Vietnam has enjoyed a sustained development, especially regarding the construction of commercial and high-rise residential buildings. Such buildings are usually responsible for important electricity consumption [1]. A few studies about the impact of the building sector in Vietnam and its related energy consumption exist and there is a real need for further investigation to create relevant database in order to elaborate an action plan to further reduce the GHGs from the building sector.

The Ministry of Construction (MOC) is implementing the Project "Energy Efficiency Improvement in Commercial and High-Rise Residential Buildings in Viet Nam" (EECB) funded by GEF/UNDP and co-financed by Viet Nam agencies/institutions and enterprises. The Project's goal is to reduce intensity of GHG emissions from the building sector in Viet Nam. The project objective is to improve the energy utilization performance of commercial and high-rise residential buildings in Viet Nam [2]. In order to implement this mission, it is essential to develop building specific energy consumption (SEC) profiles and energy benchmarking system in high-rise commercial and residential buildings in Vietnam.

For evaluating energy performance of building overall, the specific energy consumption (SEC) profile is used to describe the energy consumption of all (or part of) energy consuming systems (HVAC, lighting, water heating, cooking, electrical appliance, etc.) per area over a specific period. It must be linked to a specific type of building, under a defined climate zone [3]. In this paper, building energy consumption data is gathered from building energy surveys conducted by Ministry of Construction and international institutions (USAID, IFC…) [4]. Each collected database or information is quantitatively and qualitatively evaluated to provide SEC profile for identifying any

potential correlation in between energy consumption figures and climate zones and/or any other relevant parameters.

2. METHODOLOGY

2.1. Data source assessment

Three sets of available data of building energy consumption in Vietnam have been gathered and analyzed as described in Table 1.

Table 1. Summary of the content and the quality of existing data [4]

Data sources	Year of survey	Number of surveyed buildings	Cities	Building categories
VCEP-USAID	2016	279	Hanoi, Hai Phong, Da Nang, HCM, Can Tho	Hotel, Office, Apartment, Mall, Education, Hospital
Artelia	2008 - 2016 (various for each building)	53	Hanoi, Hai Phong, Da Nang, HCM, Can Tho, Vinh Phuc, Nam Dinh, Hue, Dong Nai	Hotel, Office, Mall, Education,
IFC	2012	59	Hanoi, Da Nang, HCM	Hotel, Office, Apartment, Mall, Education, Hospital

The VCEP - USAID data included 279 building energy surveys. They were surveyed by several survey consultants, including Artelia, IES, ECC Hanoi, ECC Da Nang, and ECC HCMC, in 2015 in 5 major cities: Hanoi, Hai Phong, Da Nang, HCMC and Can Tho. The surveyed building categories included hotels, offices, malls, educations, hospitals, and apartments. As a result, 111 out of 279 buildings surveyed in VCEP-USAID project were selected for SEC identification.

The ARTELIA data is extracted from the energy audits of 53 buildings was provided by ARTELIA. The energy audits were conducted from 2008 to 2016 in 9 cities, consisting of Hanoi, Hai Phong, Da Nang, HCM, Can Tho, Nam Dinh, Vinh Phuc, Hue, Dong Nai. Their building categories included Hotels, Offices, Educations and Malls. Due to extracted information, the names of buildings/owners were not disclosed. As a result, data of 24 out of 53 buildings provided by Artelia were selected for further analysis and application.

The IFC data on building energy consumption was gathered from IFC projects. It included 59 building energy surveys. They were survey in 2012 in 3 cities: Hanoi, Da Nang and HCMC. The building categories included hotel, office, apartment, mall, educations, and hospital. After screening, the statistical information of 46 buildings were selected for identifying the building SEC.

In our framework, we focus on 3 cities: Hanoi, Da Nang, HCMC with commercial buildings: Hotels, Offices, Malls and high-rise apartment buildings. After being screened, the number of buildings from VCEP, ARTELIA, IFC data, total number of filtered buildings is 181 with detail described in Table 2.

Table 2. Total number of existing surveyed buildings after assessment

City	Mall	Office	Hotel	Apartment building	Total
Hanoi	14	31	15	12	**72**
Da Nang	11	11	15	6	**43**
HCMC	18	17	16	15	**66**
Whole Country	43	59	46	33	**181**

2.2. Specific Energy Consumption

The Specific Energy Consumption (SEC) profile is an indicator to evaluate energy performance of building overall, which describes the energy consumption of all (or part of) energy consuming systems (HVAC, lighting, etc.) per area over a specific time period. It has to be linked to a specific type of building, under a defined climate zone. The SEC for each category of buildings is expressed by a ratio between the energy consumption over one year and the annually typical gross products of the building, such as kWh/guest.night for hotel; kWh/staff for office; kWh/m^2 for mall and apartment.

For overall comparison, the SEC is usually expressed by a ratio between the energy consumption over one year and the Gross Floor Area (GFA) of the building. In this case, SEC is deemed identical as EUI (Energy Use Index).

The SEC profile could be defined with a ratio using the following definition:

$$\mathrm{SEC} = \frac{\text{Yearly Energy Consumption (kWh)}}{\text{Comparison parameter or GFA (m}^2\text{)}} \quad (1)$$

In which:

Yearly Energy Consumption (in kWh/year): The quantity of energy consumed over one year from all energy sources - or a specific one, such as HVAC, lighting, etc.). Noted that lighting loads included the outdoor lighting on the façade. In the commercial and apartment buildings, the usage of oil, gas,... is deemed negligible and to avoid mistakes during survey, electricity is considered as a building energy consumption only.

Comparison parameter: directly linked to the activity of a given category of building (can be output based (industry) or based on occupancy or, if no other criteria, based on Gross Floor Area (m^2).

Gross Floor Area (GFA): is sum of the fully enclosed covered floor area and the unenclosed covered floor area of a building at all floor levels, including the car parking that are mechanically ventilated).

In our framework, SEC profiles are calculated for offices, hotels, malls, and high-rise apartment buildings in three typical climate zones: Northern (Hanoi), Middle (Da Nang) and Southern (HCMC) in Vietnam.

3. RESULTS AND DICUSSION

3.1. Mall's SEC profiles

Based on VCEP, ARTELIA and IFC data, SEC profiles for malls are calculated and presented in Table 3. The range of VCEP's SEC profiles was from 20 to 326kWh/m^2.yr (mean = 137); while ARTELIA from 123 to 745kWh/m^2.yr (mean = 452); and IFC from 99 to 731kWh/m^2.yr (mean = 321). The SEC profiles from ARTELIA and IFC data were comparable in terms of max and min values. While the VCEP's SEC profiles were significantly lower than those of 2 other data sources.

The higher SEC profiles from ARTELIA data could be understood that audits focused on the most energy intensive buildings, which really want to get consultant service to help them improving energy efficiency. Thus, these buildings could be considered as upper part of the market. One of the reasons to explain for the lower of VCEP's SEC could be due to the difference of building categories were applied for malls survey, including supermarkets, shopping malls and traditional markets.

Table 3. Malls' SEC profiles (kWh/m^2.year)

Data source	City	Mean	Sd.	Min	Max
VCEP	Hanoi	123	64	38	188
	Da Nang	89	55	20	163
	HCM	244	81	164	326
	Whole Country	137	86	20	326
Artelia	Hanoi	331	238	123	660
	Da Nang	400	N/A	400	400
	HCM	506	125	283	745
	Whole Country	452	169	123	745
IFC	Hanoi	281	N/A	99	464
	Da Nang	250	N/A	112	395
	HCM	432	N/A	245	731
	Whole Country	321	N/A	99	731

Based on the SEC profile of 3 data sources, the average whole country SEC profile for Malls is expected to be about 311kWh/m^2.yr, if excluding the lower values from VCEP data the average Malls' SEC profile for malls is about 387kWh/m^2.yr. This SEC value is smaller than those monitored in Hongkong. If excluding VCEP, the SEC value will be relevant to those in Hongkong (430kWh/m^2.yr) [5].

3.2. Office's SEC profiles

Table 4. Offices' SEC profiles

Data source	City	Mean	Sd.	Min	Max
VCEP	Hanoi	122	59	30	286
	Da Nang	63	21	34	88
	HCM	157	51	84	239
	Whole Country	122	60	30	286
Artelia	Hanoi	93	42	63	122
	Da Nang	N/A	N/A	N/A	N/A
	HCM	189	N/A	189	189
	Whole Country	125	63	63	189
IFC	Hanoi	163	N/A	135	211
	Da Nang	104	N/A	69	140
	HCM	175	N/A	118	231
	Whole Country	150	N/A	69	231

From VCEP, ARTELIA and IFC data, SEC profiles for offices are calculated and presented in Table 4. The range of VCEP's SEC profiles was from 30 to 286kWh/m^2.yr (mean = 122); while ARTELIA from 63 to 189kWh/m^2.yr (mean = 125); and IFC from 69 to 231kWh/m^2.yr (mean = 150). In general, SEC profiles from three data sources were comparable. Average SECs were similar from three data sources, and can be written that the SEC for offices is about 135kWh.m^2.yr. This SEC is significantly lower compared to those of office buildings in neighbor countries of Vietnam, such as 198kWh/m^2.yr in the northern China [6], 236kWh/m^2.yr in Hongkong [7] and 232kWh/m^2.yr in Singapore [8].

3.3. Hotel's SEC profiles

Based on VCEP, ARTELIA and IFC data, SEC profiles for hotels are calculated and presented in Table 5. The range of VCEP SEC profile was from 28 to 326kWh/m^2.yr (mean = 153); while ARTELIA from 35 to 410kWh/m^2.yr (mean = 234); and IFC from 52 to 467kWh/m^2.yr (mean = 245). While SEC profiles of ARTELIA and IFC were not significantly different, the VCEP SEC profiles were significantly lower than those of ARTELIA and IFC.

On the other hand, energy consumption in hotels is strongly dependent on their stand (number of star). Based on the VCEP data base, the average EUIs of hotels 4 and 5 star versus 3 star were determined. As a result, the average EUI for 4- and 5-star hotels 170kWh/m^2.year) was significantly higher than 3-star hotels (111kWh/m^2.year).

Average hotels SEC profiles from all 3 data sources is expected to be about 182kWh/m^2.year. If excluding the lower values from VCEP, average SEC is about 241kWh/m^2. Both values for hotels SEC profile in Vietnam is lower than those of hotels in Singapore - 427kWh/m^2.yr [8] and Hongkong - 542kWh/m^2.yr [9].

Table 5. Hotels' SEC profiles

Data source	City	Mean	Sd.	Min	Max
VECP	Hanoi	195	53	108	266
	Da Nang	71	48	28	203
	HCM	212	60	115	326
	Whole Country	153	85	28	326
Artelia	Hanoi	209	154	35	410
	Da Nang	N/A	N/A	N/A	N/A
	HCM	284	141	184	383
	Whole Country	234	140	35	410
IFC	Hanoi	253	N/A	203	290
	Da Nang	200	N/A	52	467
	HCM	280	N/A	246	310
	Whole Country	245	N/A	52	467

3.4. Apartment building's SEC profiles

SEC profiles for apartment buildings from VCEP and IFC data are calculated and presented in Table 6. It is noted that there is no available data from ARTELIA for apartment's SEC profile. The SEC profiles from VCEP data were from 7 to 102kWh/m^2.yr (mean = 52); and IFC from 16 to 44kWh/m^2.yr (mean = 32).

Table 6. Apartment buildings' SEC profiles

Data source	City	Mean	Sd.	Min	Max
VECP	Hanoi	57	28	14	101
	Da Nang	11	8	7	23
	HCM	62	30	16	102
	Whole Country	52	32	7	102
Artelia	Hanoi	N/A	N/A	N/A	N/A
	Da Nang	N/A	N/A	N/A	N/A
	HCM	N/A	N/A	N/A	N/A
	Whole Country	N/A	N/A	N/A	N/A
IFC	Hanoi	38	N/A	33	42
	Da Nang	32	N/A	20	44
	HCM	29	N/A	16	38
	Whole Country	32	N/A	16	44

In case of IFC, the average EUIs in 3 climate regions were quite relevant. However, it is hard to say that they were presentative for whole regions as their sample sizes were small (2, 2, 3 for Hanoi, Da Nang, HCMC, respectively). In case of VCEP, the average EUI of buildings in Da Nang was significantly lower than those in Hanoi and HCMC. The average EUIs of VCEP for Hanoi and HCMC were significantly higher than those of IFC; while the VCEP average EUI in Da Nang was significantly lower than that from IFC. However, it is very tough to discuss further due to not enough information from IFC report.

Based on the existing data, the average SEC for high rise apartment buildings could be estimated about 40kWh/m^2.

3.5. Building SEC profiles by climate regions

The SEC profiles of offices, hotels, malls and apartment buildings in Northern, Centre, Southern and across Vietnam are presented in Tables 7-10.

In general, the SEC profiles of all building categories in Da Nang were significantly lower than those in Hanoi and HCMC; while HCMC were significantly higher than others. One of main reasons could be the impact of weather condition in each region. The long and hot summer in HCMC can cause higher energy consumption by building air conditioning. Similarly, the hot and humid summer and the cold winter in Hanoi can make buildings use more energy for summer cooling and winter heating.

Beside the weather condition, the less energy consumption for all building categories in Da Nang could be influenced by social - economic and behavior of occupants. For offices, not like Hanoi and HCMC, in Da Nang, office staffs usually go home for lunch and take nap. They do not stay in office during lunch break. It can reduce the operating time of the building lighting and HVAC and leads to lower energy consumption.

Lower hotel SEC in Da Nang could be understand. Visitors when going to Da Nang usually spend their time for beach entertainment, visiting attracted and famous places in Da Nang and surrounding areas, and going out for dinner. Furthermore, they open hotel room windows for natural ventilation by sea wind blowing during the nigh time.

Lower malls' energy consumption could be explained the lower income and habit go for shopping at traditional markets of Da Nang citizens, so the malls and supermarkets in Da Nang have not many customers compared to those in Hanoi and HCMC.

Table 7. Buildings' SEC profiles in Northern of Vietnam (Hanoi)

Building Function	Mean	Sd.	Min	Max
Office	119	58	30	286
Hotel	199	91	35	410
Mall	215	188	38	660
Apartment	57	28	14	101

Table 8. Buildings' SEC profiles in Centre of Vietnam (Da Nang)

Building Function	Mean	Sd.	Min	Max
Office	63	21	34	88
Hotel	71	48	28	203
Mall	141	136	20	400
Apartment	11	8	7	23

Table 9. Buildings' SEC profiles in Southern of Vietnam (HCMC)

Building Function	Mean	Sd.	Min	Max
Office	159	50	84	239
Hotel	223	73	115	383
Mall	445	162	164	745
Apartment	62	30	16	102

Table 10. Buildings' SEC profiles across Vietnam

Building Function	Mean	Sd.	Min	Max
Office	123	59	30	286
Hotel	166	98	28	410
Mall	306	209	20	745
Apartment	52	32	7	102

3.6. Comparison of buildings' SEC profiles

Mean values of the SEC profiles of four building categories in three climate regions from IFC, VCEP and ARTELIA data are showed in Figure 1.

The SEC profiles from VCEP were significantly lower than those of IFC and ARTELIA, except apartment buildings. Specially, mall' SEC profiles from VCEP were several times lower than those from IFC and ARTELIA. As explanation, the lower VCEP's SEC profile for Malls could be due to the selection of different categories for malls. While Artelia (and

IFC) only focused on larger super markets, which use more equipment with high capacity, such as bread stoves and cold storages. Furthermore, within VCEP database, a malls' SEC profile in Da Nang was significantly lower than those in Hanoi and HCMC. The difference of SEC profiles among data sources could be due to the use of different methodologies for building energy survey.

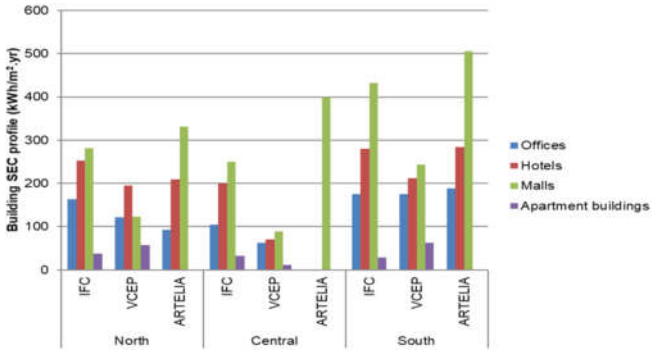

Figure 1. Buildings' SEC profiles from IFC, VCEP and ARTELIA

In case of VCEP database, the discrepancies of the SEC profiles could be explained by the application of many surveyed building categories (16 categories). In additional, Methods and procedures of 5 dirferent surveyors (ECC Ha Noi, ECC Da Nang, ECC HCMC, Artelia and IES) involved to VCEP building surveys could make differences and uncertainties during the survey.

4. CONCLUSION

The different SEC profiles among other data sources, as well as among climate regions could be understood by various methodologies for energy survey and audit. On the other hand, the differences could be explained by many building topologies were applied. It made the sample size for each building category not large enough for statistical analysis and assessment. In additional, various surveyors in different teams can also make the values of the SEC profiles variant.

Different energy survey purposes and methodologies were applied for different data (IFC versus VCEP versus ARTELIA). It made their building SEC profiles different. Simultaneously, the use of many building categories in various regions/provinces across the country made building sample sizes not large enough for statistical assessment. Building EUI/SEC profiles were drafted but mainly based on GFA (m^2), not for building specific activities; By building categories and climate regions, the building sample size(s) were small.

Many discrepancies on EUI/SEC between a given typology of building among data sources (IFC versus VCEP versus ARTELIA), and even in the same data source (in case of VCEP). Calculated building EUI/SEC profiles in Vietnam were significantly lower than those in neighbor countries, such as China, Hong Kong, Singapore.

From above lessons learnt, we suggest for the next building energy survey of Ministry of Construction:

- Focusing on only 4 categories of buildings, especially for hotels, malls and offices;
- Focusing on single-use buildings to avoid mistakes during the survey;
- Selecting buildings constructed from 2005 up to now;
- Focusing on total EUI to follow up the energy performance is probably not the best way to proceed. Focus on the main energy usage, consisting of Lighting and HVAC must be better.
- Focus on a best effort methodology.

REFERENCES

[1]. United Nations Development Programme, 2016. *Project document*. Energy Efficiency Improvement in Commercial and High-Rise Residential Buildings in Viet Nam Project.

[2]. Jallade N., Tran NQ., 2018. *Development of Specific Energy Consumption (SEC) profiles and Energy benchmarking system – Inception Report*. Energy Efficiency Improvement in Commercial and High-Rise Residential Buildings in Viet Nam Project.

[3]. Seng AK., Neng J., Ling CY., Zhimin C., Loke CS., Hong J., Teo F., 2020. *BCA Building Energy Benchmarking Report*. Building and Construction Authority of Singapore.

[4]. Tran NQ., Dang HA., Mac VD., 2018. *Existing energy comsumption data analysis for defining building energy survey scope, methodology and form – Technical Report*. Energy Efficiency Improvement in Commercial and High-Rise Residential Buildings in Viet Nam Project.

[5]. Lam JC., Li DHW., 2003. *Electricity consumption characteristics in shopping malls in subtropical climates*. Energy Conversion and Management, 44: 1391-1398.

[6]. Ma H., Du N., Yu S., Lu W., Zhang Z., Deng N., et al, 2017. *Analysis of typical public building energy consumption in northern China*. Energy and Buildings, 136: 139-150.

[7]. Jing R., Wang M., Zhang R., Li N., Zhao Y., 2017. *A study on energy performance of 30 commercial office buildings in Hong Kon*g. Energy and Buildings, 144: 117-128.

[8]. Priyadarsini R., Xuchao W., Eang LS., 2009. *A study on energy performance of hotel buildings in Singapore*. Energy and Buildings, 41: 1319-1324.

[9]. Deng SM., Burnett J., 2000. *A study of energy performance of hotel buildings in Hong Kong*. Energy and Buildings, 31: 7-12.

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