Energy Analysis of the Commercial Sector in Thailand: Potential Savings of Selected Options in Commercial Buildings

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Abstract: This paper presents an overview of the energy used characteristics in Thailand. The analysis focuses on the historical and current energy consumption patterns in the whole country, especially in the commercial sector. The total energy consumption database between 1988 and 2002 was reviewed and discussed to present the past, current and future trends. In this paper, the commercial electricity consumption, especially electricity used in buildings, is highlighted and remarked. Moreover, electricity used can be divided into three major electricity end-users, namely, air-conditioning, lighting and other system within five different building types, which are office, hospital, hotel, education and retail stores buildings. In this paper, five reference building types are modeled based on building database in order to study and evaluate the potential savings of selected options in commercial buildings. In hot and humid climate, the buildings with space conditioned highly consume electricity due to excessive lighting, heavy heat gain through the building envelope, heavy air-conditioning usage and high ventilation from moisture removable. Therefore, the selected energy saving options are concerned mainly in lighting, building envelope and air-conditioning system. Next, the selected energy saving options are applied to the buildings to investigate the changes in electricity consumption. Finally, a building energy-simulation software is used to evaluate the impacts of selected saving options on the commercial electricity use.

Keywords: Commercial Buildings, Electricity Consumption, Reference Buildings, Energy Conservation, Electricity Saving.

1. INTRODUCTION

In the past decade, the energy consumption have increased at a rapid rate because of economic and population growth. In Thailand, there are the four major electricity-consuming sectors consisting of industrial sector, commercial sector, residential sector and agriculture sector. To begin with, according to the industrial sector, electricity consumption rose from 36,200 GWh in 1999 to 48,300 GWh in 2003 accounting for an annual growth rate of 8.34%. In the commercial sector, electricity consumption rose from 19,300 GWh in 1999 to 25,400 GWh in 2003 accounting for an annual growth rate of 7.81%. In the residential sector, electricity consumption rose from 18,200 GWh in 1999 to 23,300 GWh in 2003 accounting for an annual growth rate of 7.08%. In the agriculture sector, electricity consumption rose from 164 GWh in 1999 to 228 GWh in 2003 accounting for an annual growth rate of 9.76%. Secondly, the industrial sector is the most electricity-consuming sector following by the residential sector, the commercial sector and the agriculture sector. Regarding electricity consumption growth rate, the agriculture sector is the most increased following by the industrial sector, the commercial sector and the residential sector respectively.

2. ELECTRICITY CONSUMPTION IN THAILAND

2.1 Whole country

In this section, the electricity consumption patterns of the whole country between 1988 and 2003 [1] are summarized in the Figure. 1. At the glance, we can see in the diagram that there are 2 parts of the growth of electricity consumption. The first part started from 1988 to 1997 and the second part started from 1998 to 2003. Regarding the first part, the world economic had increased rapidly in that period because of the increasing in technology, living standards, and energy consumption. Therefore, the electricity consumption had increased for developing the technology, providing comfortable in living and building the business assets from nearly 28,100 GWh to 82,000 GWh accounting for approximately 54,000 GWh increase. Regarding the second part, the economic crisis occurred in the beginning of this period especially in Southeast Asia countries resulting in the slight fall of electricity consumption in 1998 compared with 1997. After that, the electricity consumption had rose moderately again from 80,000 GWh in 1998 to 106,000 in 2003.

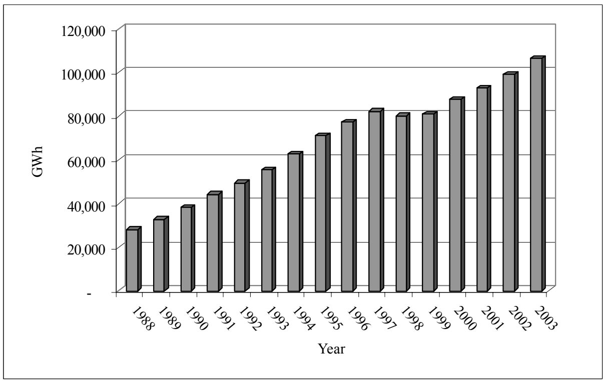

Fig. 1 Electricity consumption between 1988-2003.

Table 1 Electricity consumption (GWh)

Year	Sector: Residential	Commercial	Industrial	Agriculture & others
1999	18,171	19,316	36,180	7,124
2000	19,393	21,050	39,472	7,682
2001	21,168	22,129	41,587	7,982
2002	22,045	23,693	44,727	8,658
2003	23,315	25,350	48,252	9,220

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Table 2 Building database

Parameters and units	Building types				
	Office	Hospital	Hotel	Retail stores	Education
Number of samples	464	163	190	151	122
Total floor area (m^2)	22	5.45	6.64	8.38	10.33
Usage area (m^2)	19.33	5.44	6.0	5.98	11.18
Air-cond area (m^2)	6.69	2.48	4.16	4.74	3.42
Total electricity consumption (GWh)	1,794	580	1,043	1,427	557
OTTV (W/m^2)	56.77	55.46	56.14	42.91	56.18
RTTV (W/m^2)	39.06	39.05	26.48	22.12	36.93
WWR	23.40	28.68	35.93	20.47	26.61
% Air-condition	50.75	58.5	55.31	45.2	52.76
% Others	30.18	19.35	23.59	33.36	24.1
% Light	19.07	22.14	21.1	21.45	23.4

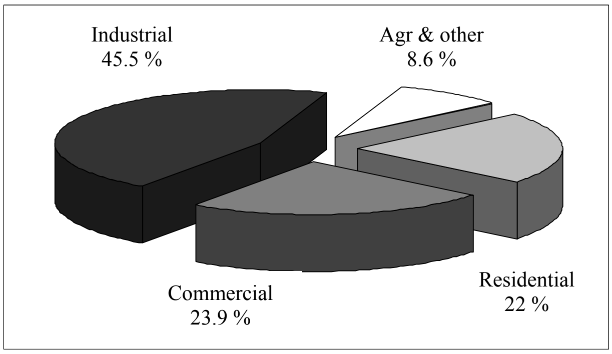

Fig. 2 Electricity consumption pattern of the whole country at 2003.

2.2 The commercial sector

In 2003, Thai commercial sector consumes electricity about 25,350 GWh per year, accounting for 24% of electricity consumption in the whole country. The electricity consumption pattern between 1999 and 2003 is presented in Figure 2. Furthermore, referring to DEDE building database, the large commercial buildings consume more than a half of commercial electricity used. The details of commercial buildings are described in the following section.

3. COMMERCIAL BUILDINGS

The purpose of this section is to represent the details of commercial buildings and the reference buildings that developed from the database. Moreover, five reference buildings are used as case studies to practice energy conservation opportunities and calculate electricity saving from the selected options.

3.1 Building database

In this paper, the building database collected by DEDE [2] and the earlier studies [3] are used to develop reference buildings. To be precise, in Thailand, large commercial buildings are classified into 5 building types; office (OFF), hospital (HS), hotel (HT), retail stores (RT), education buildings; and the details of building database are summarized in Table 2. It can be seen from Table 2 that total floor space area of building database is approximately 52.8 million m^2 with the corresponding electricity consumption of 5,400 GWh per year. Moreover, we can see from Figure. 3 that the office buildings share the most floor area of m^2 following by hospital, hotel, retail stores and education buildings respectively.

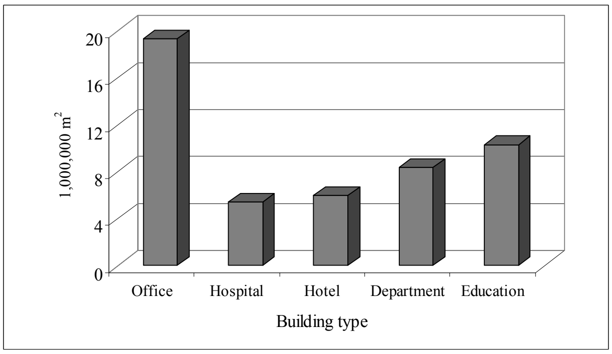

Fig. 3 Floor area shared of commercial buildings.

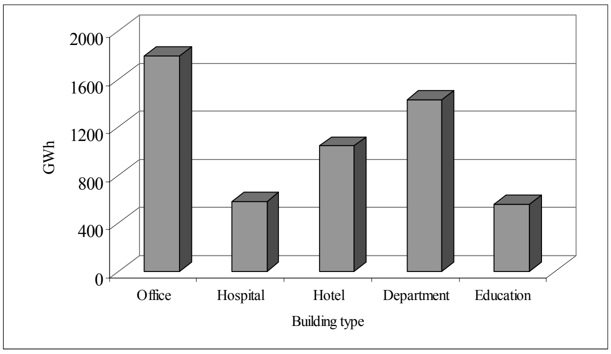

Fig. 4 Electricity consumption of commercial buildings.

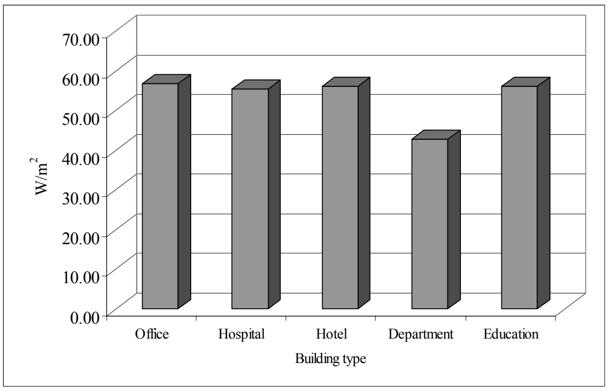

Fig. 5 OTTV of commercial buildings.

Table 3 Reference buildings

Parameters and units	Building types				
	Office	Hospital	Hotel	Retail stores	Education
General characteristics					
Total floor area (m^2)	24,192	17,246	11,448	8,280	9,621
Air-Conditioned area (m^2)	18,359	9,064	8,307	6,630	5,259
Number of storeies	12	8	8	3	6
Envelope area (m^2)	8,226	5,357	4,845	3,173	5,342
WWR	0.3	0.297	0.3	0.11	0.18
Total electricity use (MWh)	4,962.5	2,351.3	2,294.9	1,957	1,011.1
EUI (kWh/year)	205.13	136.34	200.00	236.34	105.1
% Lighting	18.67	19.80	19.12	21.53	19.24
% Air-conditioning	51.61	63.03	59.78	45.63	60.74
% Others	29.72	17.17	21.10	32.84	20.03
Other characteristics					
Thermal conductance of window: U_f (W/m^2-°C)	5.58	5.58	5.58	5.58	5.58
Thermal conductance of window: U_w (W/m^2-°C)	2.84	2.84	2.84	2.84	2.84
Shading coefficient: SC	0.52	0.52	0.52	0.52	0.52
Lighting power: LP (W/m^2)	12.82	9.59	11.86	11.17	8.61
Equipment power: EP (W/m^2)	20.04	5.77	12.28	16.22	9.55
OTTV (W/m^2)	56.74	55.52	55.48	44.72	49.27
Temp set-point (°C)	24.5	25.0	25.0	25.0	24.5
Chiller's COP	4.5	4.5	4.5	4.5	4.25

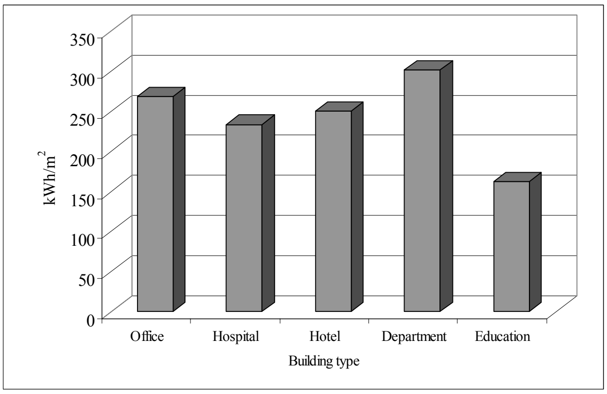

Fig. 6 Energy use intensity of commercial buildings.

3.2 The generic office buildings

In energy simulation, the building simulation program, DOE-2.1E [4], is used to model five reference buildings: office, hotel, hospital, retail store and education buildings. The reference buildings are modeled based on 2 components that are building envelope and electricity used characteristics.

Concerning building envelope component, OTTV is used to be an index to develop the models. To be precise, the parameters relating to building envelope are walls and windows, which can be represented by the following parameters:

(1) Thermal conductance of window. U_f
(2) Thermal conductance of wall. U_w
(3) Shading coefficient of window. SC
(4) Window-to-wall ratio. WWR

To sum up, four parameters are in the OTTV equation [5]. Therefore, OTTV can be used as an index to develop building envelope characteristics.

Concerning electricity used component, we used four parameters to develop the models. The parameters are listed according to the electricity use intensity (kWh/m^2)

(1) Percentage of electricity used in air-conditioning
(2) Percentage of electricity used in lighting.
(3) Percentage of electricity used in equipment.
(4) The total electricity used intensity

In addition, the details of reference buildings are presented in Table 3. Moreover, the important parameters are highlighted and compared in Figs 7, 8, and 9.

According to Fig. 7, the bar chart compares the electricity used intensity (kWh/m^2) of the models. It can be seen from the figure that retail store model has the highest EUI at approximately 225 kWh/m^2, while education model has the lowest EUI at nearly 100 kWh/m^2.

In Fig. 8, the bar chart represents the floor space area of the models. We can see from the chart that office model uses the highest floor space area, while retail store models uses the lowest one.

In Fig. 9, this figure shows percentage of electricity used in air-conditioning system that consumed more that 50% of total electricity used for all of the models because in hot and humid country electricity in air-conditioning system was used to remove heat and moisture in conditioned space.

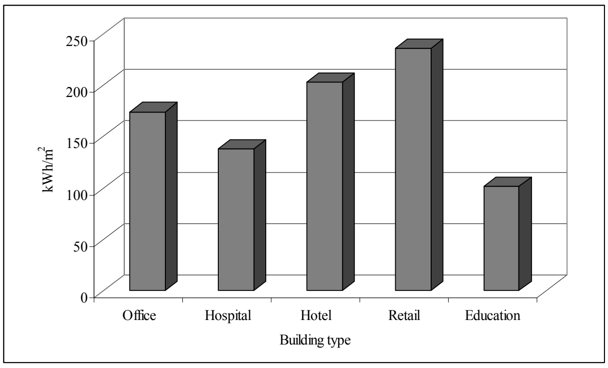

Fig. 7 Energy use intensity of reference buildings.

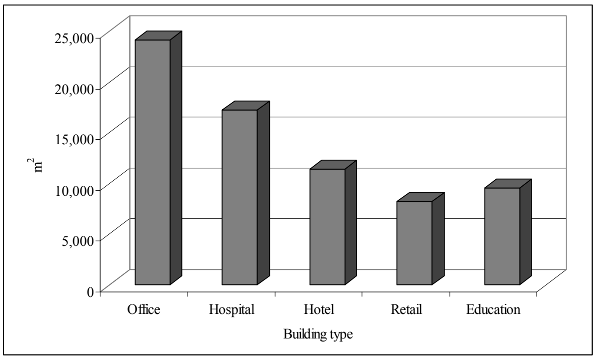

Fig. 8 Floor space area of reference buildings.

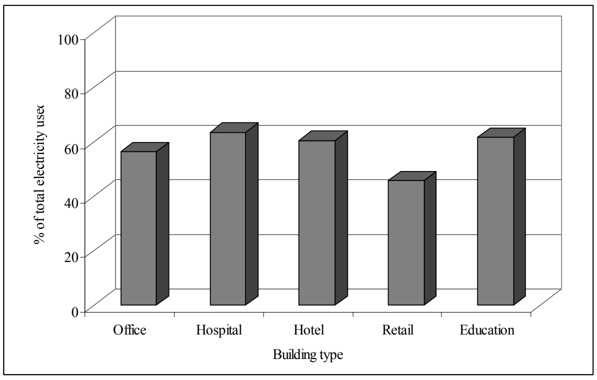

Fig. 9 Electricity used in air-conditioning system.

4.1 Energy conservation opportunities

Generally, the energy conservation opportunities in buildings can be divided by three systems:

(1) Air-conditioning system.
(2) Lighting system.
(3) Equipment system.

In large commercial buildings, more than a half of electricity used is consumed by space-conditioning purpose especially in Thailand where the weather is hot and humid. The other parts of electricity used supply to lighting system and equipment system.

In air-conditioning system, air-conditioning is the process to maintain temperature and humidity inside the space. Regarding the inside heat gain, there are 4 heat sources: lighting, equipment, occupancy, and natural ventilation. Regarding the outside heat gain, it is the heat transferred into conditioned space through the building envelop. In plant system, the COP of chiller is another sensitive parameter that can be improved.

Next, lighting system is the second part of electricity consuming in commercial buildings. In the past, there was less evidence in energy conservation in this system or in the other word, lighting have been usually used over the standard. Therefore, it has high potential to adapt energy efficient-use in this system.

Lastly, equipment system relates to all equipments in buildings such as personal computer, monitor, printer, refrigeration, television, radio, etc. We calculate equipment power by summing all of equipment power and divided by total floor space area.

4.2 Selected options

It can be divided the energy conservation options into 2 parts. Firstly, for existing building stocks, the energy conservation in existing building stocks was done by selecting 8 parameters to study. The improvements of efficiency are studied using the recommendation in the earlier study [6]. The eight parameters are selected and listed as follows:

(1) Lighting power density
(2) Equipment power density
(3) Shading coefficient of window
(4) Thermal conductance of window
(5) Thermal conductance of wall
(6) COP of chiller plants

Lighting power density

Using natural lighting and efficient lighting system can reduce the lighting power density. To be precise, daylighting can be used in order to reduce electric lighting. Another option is to improve lighting components such as installing electronic ballast, using efficient starter, etc. Not only saving directly from electricity used but also we can save electricity from air-conditioning system by reducing the heat gain from lighting to the cooling load.

Equipment power density

Similar to lighting system, electricity used can be reduced by improving energy-efficient used. For example, we can reduce electricity in personal computer system such as use short stand-by time in monitor, turn off unused equipment, set up the equipment schedules, etc.

Shading coefficient of window

The easy way to reduce solar radiation transferred through the window is to add film level into the inside surface because the film can reduce the heat by reflecting solar radiation. Therefore, it can be reduced shading coefficient of window.

Thermal conductance of window

At present, commercial building envelope has been almost applied with high window-to-wall ratio. Therefore, heat conduction through the window is a sensitive factor to electricity used. We can improve its efficiency by changing glass types such as double-glazing glass.

Thermal conductance of wall

To reduce thermal conductance of wall, the insulation can be used to add at the opaque wall that reducing conduction heat gain through the wall.

COP of chiller plants

Improving chiller's COP is another interested options to reduce the electricity used. As mention before, more than half of electricity was consumed for space-conditioned purpose.

Secondly, for new building stocks, the energy conservation in new building stocks was done in similar to existing building stocks by adding window-to-wall ratio into selected options.

Table 4 Selected options and their energy-efficient used

Selected options	Unit	Base case	Efficiency improvement or new values	New values for energy-efficient used
Lighting power density	W/m^2	See Table. 3	48 %	Using T5 lamp with electronic ballast
Equipment power density	W/m^2	See Table. 3	20 %	Case study
Shading coefficient of window		0.52	0.33 (new value)	Double solar tag with Low-E 24 mm SC=0.33
Window-to-wall ratio		See Table. 3	20 %	Case study
Thermal conductance of window	W/m^2-°C	5.58	3.044 (new value)	Double solar tag with Low-E 24 mm SC=0.33
Thermal conductance of wall	W/m^2-°C	2.84	0.944 (new value)	Brick with 20-mm plastering mortar
COP of chiller plants		See Table. 3	7 (new value)	Maximum possible COP

4.3 Energy simulations

The simulation tool for building energy analysis, DOE-2.1E, is used to simulate building energy used with the local weather data. In addition, we used the weather file [7] using Bangkok as the local weather data. The energy simulation runs are performed following percentage of efficiency improvement of each parameter in Table 4.

5. RESULTS

5.1 Parameterization study

Firstly, the simulation runs of base case options are performed, and full details of energy used characteristics are presented in Table 3. To be precise, the important details of base cases that used to calculate electricity reduction are summarized in Table 5.

Table 5 Electricity used of reference buildings

Parameter	Electricity used (MWh) and sharing (%)				
	OFF	HS	HT	RT	ED
Lighting sharing	520.60	248.80	218.90	215.70	106.30
Equipment sharing	808.60	54.20	113.40	290.50	53.90
Air-conditioning sharing	154.20	167.40	80.00	31.30	61.60
Total electricity used (MWh)	69.90	66.20	26.00	16.90	47.80

Secondly, eight simulation runs for each reference building are performed to generate energy information database. Next, the total electricity reduction of selected options are calculated and compared.

5.2 Impacts on the electricity used of reference buildings

The total electricity reduction from selected options is presented in Table 6 by building types. It can be seen from the table that the equipment efficiency improvement in office building is the most electricity saving at approximately 800 MWh, while the decreases of window-to-wall ratio save the lowest of electricity saving. In addition, the equipment efficiency improvement can reduce electricity used at the maximum percentage of 15 % as presented in Fig. 10.

In the case of combining all of options together, the results from Fig. 11 shows that it can be saved electricity used in reference buildings around 40 %-50 % of the base case options. The combination of all options in education buildings is the highest of electricity saving, while in hotel buildings is the lowest of electricity saving.

Table 6 Electricity reduction of reference buildings

Parameter	Reduction of electricity (MWh)				
	OFF	HS	HT	RT	ED
LP	520.60	248.80	218.90	215.70	106.30
EP	808.60	54.20	113.40	290.50	53.90
SC	154.20	167.40	80.00	31.30	61.60
WWR	69.90	66.20	26.00	16.90	47.80
Uw	365.80	242.80	186.50	120.70	189.20
Uf	65.70	74.30	41.30	11.00	16.90
COP	590.10	281.60	278.40	166.40	130.90
Total	2329.90	972.00	915.70	794.90	496.00

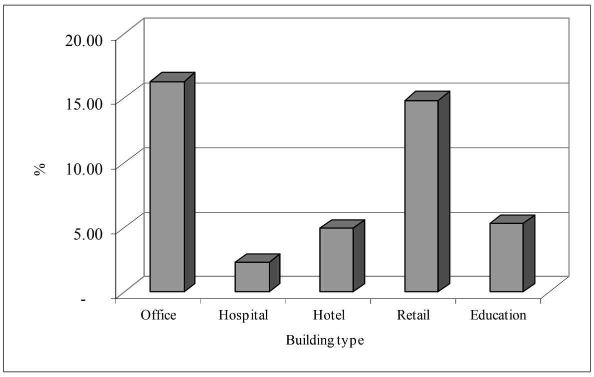

Fig. 10 Electricity reduction percentage of equipment options.

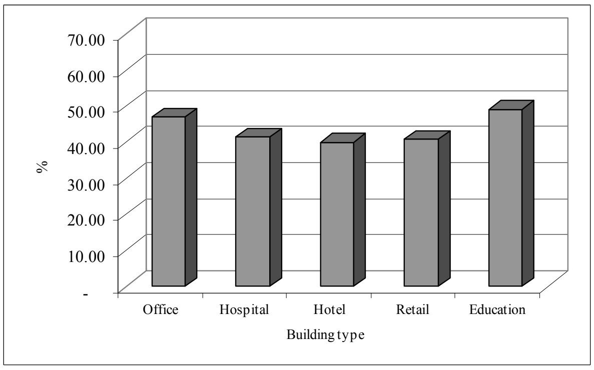

Fig. 11 Electricity reduction percentage of all selected options.

5.3 Impacts on the total electricity used in the commercial sector

Energy information database from the simulation runs is used further to determine the saving impacts on electricity used in the commercial sector. The total electricity saving can be calculated by the multiply of the electricity saving per unit air-conditioning area of each selected option and the total air-conditioning area of each buildings from Table 2. Moreover, the total electricity saving from each building types for selected option are shown in Table 7.

Table 7 Total electricity reduction in the commercial sector

Parameter	Reduction of electricity (GWh)				
	OFF	HS	HT	RT	ED
LP	189.61	68.05	109.71	154.06	69.16
EP	294.50	14.83	56.84	207.49	35.07
SC	56.16	45.79	40.10	22.36	40.08
WWR	25.46	18.11	13.03	12.07	31.10
U_w	133.23	66.41	93.48	86.21	123.09
U_f	23.93	20.32	20.70	7.86	10.99
COP	214.92	77.03	139.54	118.85	85.16

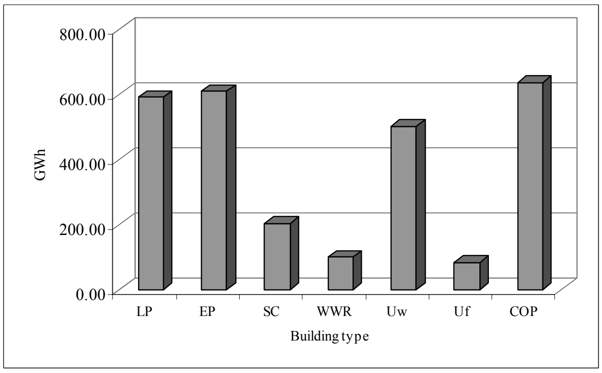

Fig. 12 Electricity saving by selected options.

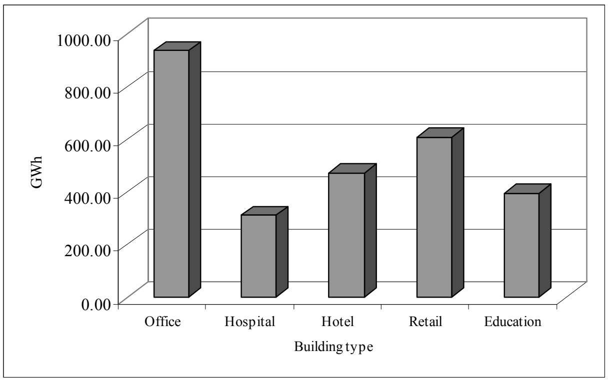

Fig. 13 Total electricity reduction of all selected options.

Fig. 12 compares electricity savings among parameters. The results show that efficiency improvement of COP can be achieved the highest of electricity saving, while it is the lowest in the case of thermal conductivity of wall.

Lastly, the total electricity saving of all selected options combination is represented in Fig. 13 by building type. The figure shows that for the building in the database the highest electricity saving in the office buildings is at around 900 GWh and the lowest in the hospital buildings is at just under 300 GWh.

6. CONCLUSIONS

The paper reviews the electricity consumption in Thailand between 1988 and 2003. The analysis of electricity saving from all selected options of energy conservation can be saved electricity around 2,700 GWh. It can be accounted about 10.75 % and 2.57 % of electricity consumption in the commercial sector and the whole country in 2003, respectively.

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