Economic analysis on renovating lighting system on existing building: A case study in Thailand

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Abstract

This paper proposed economic analysis on implementation of energy efficiency improvement measure in lighting system of existing building. The study used education purposed building in Thailand as case study building. Two important economic parameters, discounted payback period and internal return rate (IRR), will be used to determine the feasibility to invest in the proposed measured. The result has shown the possibility to investing in renovate lighting system in existing with better energy saving and attractive economical parameter. This methodology and result from case study building can be used to design the suitable subsidy policy for energy efficiency improvement by renovate existing building in the future.

Keywords: Lighting System, Building Renovation, DIALux, Economic Analysis

1. Introduction

Electrical energy issue has become the main challenge in the past decade due to rapid rapidly growth in economic and population. This trend results in increasing in energy consumption and will further rising until generating capacity cannot keep up with demand. One of the measure that can be implemented without increase number of power plant and risk the damaged to environment is improving energy efficiency. Thailand government also set the target in energy efficiency development plan (EEDP) to reduce energy intensity (EI) by 30% in 2036 or from 187,142 ktoe to 131,000 ktoe compare to business as usual (BAU) case [1]. This plan also aims to improve energy efficiency and reduce energy usage in building. The main energy consumption in building is Heating, ventilation, and air conditioning (HVAC) system which take up 50% proportions of energy usage following by lighting system around 25% [2]. If the measure can address these systems, it can greatly reduce overall energy usage in the building.

The Department of Alternative Energy Development and Efficiency (DEDE) also issues "Energy Conservation Promotion Act (No. 2) B.E. 2550" to supervise, promote, and assist the energy conservation measure in order to achieved energy conservation goals, the. This act has stated that Construction or modification of building such as Office, Hotel, Education place, Department store etc. if total area in all stories in the same building larger than 2,000 square meters, it must be designed for energy conservation according to this Ministerial Regulation [3]. The energy efficiency indicator in lighting system under the discussed act calculated from electric consumption in lighting system excluding car parking area. The light output from lighting equipment must complied with lighting standard for every types usage. The lighting power density according to the act can be summarized in Table 1.

Table 1. Lighting power density

Type of Building	Highest power of lighting (Watt per square meter of used area)
(a) Education place, Office	14
(b) Theatre, Trade Centre, Place of Entertainment Service, Building for congregation	18
(c) Hotel, Clinic, Condominium	12

The comparative study on building rehabilitation and demolition in perspective of both economic and environment has been presented [4]. The result shown that renovate an existing building is a better way to improve energy efficiency with less impact on environmental. The lighting emitting diode (LED) luminaire technology and its performance in various aspect such as energy performance, lighting quality, and economic etc. has been reviewed [5]. In [6], the review on methodology to improving energy efficiency in lighting system of office building has been discussed. In term of economic analysis, the cost-effectiveness analysis (CEA) has been used to analyse energy efficiency measures [7]. The economic analysis and reliability issue in case of implement new high efficiency technology such as LED has been discussed [8].

It can be seen from literature review that improvement in lighting system has potential to significantly improve energy efficiency in building. This paper proposed energy performance and economic analysis on renovate existing building with lighting system under consideration. The economic parameters, discounted payback period and internal return rate (IRR), has been used to analyse the feasibility to invest in energy efficiency improvement measure. The methodology and result can be used to support investor that interest in investing in renovate existing building in the future.

2. Building Layout

The building using as case study is a lecturer building, fall in category of education purposed building, in Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang. It is 12 stories building with total floor area 22,977m2 and the overview design of the building is shown in Fig. 1 and the floor plan with layout of equipment in lighting system is shown Fig. 2.

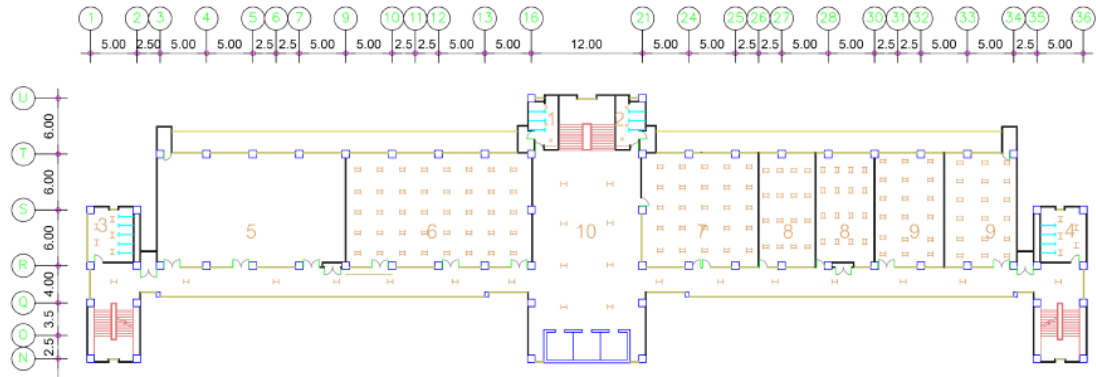Fig. 1. Building under case study.

Fig. 2. Lighting system layout in case study building.

3. Result

The economic analysis on energy efficiency measures that will be implement on case study building has been done. Two economic parameters, internal return rate (IRR) and discounted payback period, will be used as a factor to decide the feasibility to invest and the DIALux software has been used to verify the light output for all replacement luminaire as shown in Fig. 3. The lighting standard has indicated that illuminance on working plane must be higher than 500 lux in order to obtained quality of light suitable for occupancy in the building.
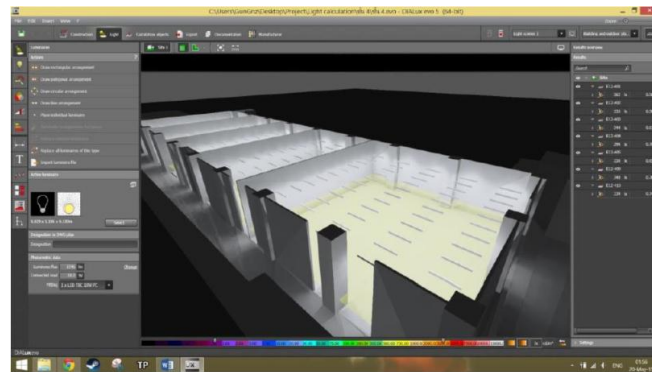

Fig. 3. DIALux simulation

3.1. Energy performance

Currently, the case study building currently used T8 fluorescent luminaire. In order to improve energy efficiency in lighting system, the lighting equipment must be replaced with more efficient luminaire. So, the case study will be consisting of three cases as followed; replace fluorescent T8 luminaire with fluorescent T5 luminaire, LED tube and LED tube 18w. The three types of luminaire replacement have been verified using DIALux software that these types of luminaire have illuminance value on working plane more than 500 lux. The specification and cost of current and replacement equipment in lighting system can be summarize as shown in Table 2. The power consumption and light output density compare to standard are shown in Table 3. The comparison between three types of replacement equipment using in this study indicated that the better efficacy results in higher cost due to the implementation of newer technology. However, the significant increase in energy saving annual might provide advantage in the long-term.

Table 2. Comparison of current and renovate equipment in lighting system

Current equipment						
Equipment	Power (W)	Other equipment	Lifetime (hrs)	Lumen (lm)	Efficacy (lm/w)	Cost ($)
Fluorescent T8	46	Induction ballast	10,000	2,710	58.91	-
Replacement equipment						
Fluorescent T5	28	Electronic ballast	20,000.00	2,800.00	96.55	4.24
LED T8 20w	20	-	15,000.00	2,100.00	105.00	6.41
LED T8 18w	18	-	30,000.00	2,100.00	116.67	13.13

Table 3. Power consumption in lighting system

Equipment	Number of Luminaire	Floor Area (m^2)	Power consumption (kw)	Energy saving (kWh/yrs.)	Lighting power density (w/m^2)	Standard (w/m^2)
Fluorescent T8			237.22	-	10.32	
Fluorescent T5	5,157	22,977.00	149.55	6,424.60	6.51	14
LED 20w			103.14	9,825.86	4.49	
LED 18w			92.83	10,581.69	4.04	

3.2. Economic analysis

The economic analysis in this research will used two economic indicators, IRR and discounted payback period, to dictate the feasibility of the lighting renovation projects. The result in term of economic analysis from three proposed energy efficiency improvement measures are shown in Table. 4. The calculation based on current electric Thailand electric price at 3.98 THB/kWh or 0.121 USD/kWh (1 USD = 32.75 THB) and forecast of inflation rate at 2%.

It can be seen from the table that replacement from Fluorescent T8 luminaire to T5, LED 20w and LED 18w luminaire can achieved discounted payback period 1.25, 1.10 and 1.90 year with IRR value 77.14%, 88.02% and 47.56% respectively. The reason for LED longer payback period and less IRR value due to higher initial cost. However, the long-term value will be better from higher energy saving cost and less maintenance.

Table 4. Economic analysis for lighting system renovation

Luminaire	Installation cost ($)	Energy cost saving ($/yr.)	Discounted Payback period (yrs.)	IRR (%)
T5	29,761.01	25,569.90	1.25	77.14%
LED 20w	40,941.07	39,106.91	1.10	88.02%
LED 18w	75,583.51	42,115.13	1.90	47.56%

4. Conclusion

This paper present economic analysis on energy efficiency improvement measures in lighting system using education purposed building in Thailand as a case study. The analysis on energy performance and economic analysis has been done in this research and can be summarize as followed;

In case of energy performance, the new replacement luminaire has better efficacy and long-life time which can achieved much more energy saving and less maintain cost in the long run. The Lighting power density must be complied Thailand's building energy code and lighting standard, for educational purposed building, must be lower than 14 watts per square meter and has illuminance value more than

500 lux on working plane respectively. The result of all three types of luminaire replacement are within the standard value with LED shown the energy efficient with energy performance. In addition, the 18 w LED has better efficacy and light output density.

In term of economics analysis, the result shown that all replacement case studies can achieved discounted payback period less than two year with IRR attractive IRR value. The LED tube 18w has IRR value is less than other case due to higher luminaire cost. However, it will be achieved more energy cost saving in the long-term due to less power consumption and long-life time.

Acknowledgements

Conflict of Interest

The authors declare no conflict of interest.

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