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Feasibility analysis on building air-condition system renovation: Thailand case study

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Abstract. Energy efficiency improvement in existing buildings has been an interesting issue for researcher especially in heating, ventilation, and air conditioning (HVAC) system that appear to take up the large proportion of energy consumption. So, this paper aims to present an analysis on renovation measure to improve energy efficiency in building air-condition system. The study has been done using multi-purpose building in Thailand as a case study. The analysis of proposed renovation measurement will be done in both energy performance and economic perspective. Standard from Thailand building energy code is also taken into consideration when selecting equipment for replacement. The obtained result has indicated the suitability of proposed measure application in building with significant energy efficiency improvement and attractive economic parameter.

1. Introduction

Energy consumption in Thailand's urban area has been rapidly increasing due to significant growth in economic and population that lead to attain high-rise building with significant energy demand. The commercial and residential sections, that most buildings are based on these two categories, have taken up a significant proportion of overall energy consumption up to 22% according to 2016 Thailand energy statistic [1]. Thus, the government has set 20-Year Energy Efficiency Development that aims to reduce energy intensity (EI) by 20% (30,000 ktoe) from business-as-usual (BAU) case in 2030 with 17.6% share of energy saving from building in residential and commercial sectors [2]. One of the steps that government is implementing to achieve the target is elected "Building Energy Code (BEC)" as a law in 1992 for both newly constructed and renovated existing building with total area over 2,000 m^2 to be complied with this code prior to submission for approval [3]. This standard regulated building energy performance in six main perspectives that have significant impact on overall energy consumption; building envelope, air-conditioning, lighting, hot water, renewable energy and whole building energy usage.

In Thailand, heating, ventilation, and air conditioning (HVAC) system especially air-condition has taken up to 60% of overall energy consumption in building due to Thailand location in tropical climate zone. This results in average hot and humidity weather that requires a lot of cooling capacity in order to achieve comfort zone for building occupant [4]. So, air-condition system will be main focus for researcher to improve energy efficiency by various measures, methodologies and technologies.

Literature review in field of energy efficiency improvement measure, impact and case studies especially in air-condition system has been done in this research [5]-[9]. The energy efficiency technologies and measures for non-residential building in European Union have been presented [5]. Research by Jin has presented the model and simulation to evaluate the air-condition usage pattern based on occupancy behaviour [6]. The field study on air-condition in office building in China has been presented [7]. The life cycle and economic analysis on air condition has been studied to evaluate impact on environment and economic perspective [8]. The energy saving measure in air-condition in case of Thailand has been also presented [9]. However, the measure presented in this paper only focuses on large size air-condition system.

From the literature review, it can be seen that HVAC system, especially air-conditioning system in case of building located in tropical climate such as Thailand, has taken up significant percentage of overall energy consumption in building, thus research on measure to improve energy efficiency in air-condition system with feasibility for implementing those measures in terms of economic perspective must be evaluated. Hence, this paper presents an analysis on air-condition renovation measure using multi-purposed building located in Bangkok, Thailand as a case study. The performance analysis on proposed measure has been done in both energy performance and economic perspective. The result and methodology from case study can be applied to other projects to improve energy efficiency in both existing and newly constructed building in the future.

2. Case study building

The case study in this research is 12-floor multi-purposed building at Faculty of Engineering, King's Mongkut's Institute of Technology Ladkrabang (KMITL) located in Bangkok, Thailand. The overall exterior of the simulated building is illustrated in Fig. 1. The floor plan of the building, location of installed outdoor and indoor air-condition unit in the building are depicted in Fig. 2. The figure shows an example of 9th floor layout. However, the building has similar floor layout throughout 1st to 12th floors with minor adjustment on room section on each floor, thus the area of room with air condition is very similar on each floor. The estimated total floor area of the building is 25,000 m^2 and floor area of the room with air-conditioning installed is 13,900 m^2.

Figure 1. Exterior of the building in case study.

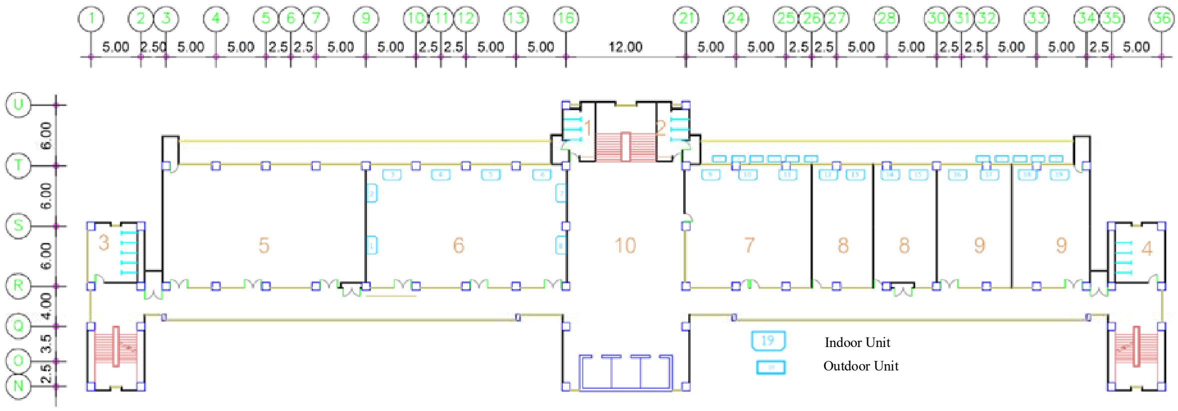

Figure 2. Floor plan of case study building (9th Floor).

According to BEC standard, the code only used as Coefficient of performance (COP) or Energy efficiency ratio (EER) as parameter to evaluate energy performance of split types air-condition, the standard has categorized air-condition into three categories according to its sizing as presented in Table. 1 [3]. However, standard for spilt types air-condition only covers for sizing up to 17.6 kW. For sizing larger than 17.6 kW, COP and EER value will be using 2.56 and 8.74 respectively. This value has been used as a reference for choosing air-condition size and types that will be installed in the building.

Table 1. Energy performance requirements for split types air-condition

Type and Size	COP (EER)
Less than 3,500 watts (0.995 RFT)	2.82 (9.62)
Between 3,500 watts and 17,600 watts (5.00 RFT)	2.82 (9.62)
Greater than 17,600 watts (5.00 RFT)	2.56 (8.74)

3. Analysis and result

3.1. Energy Performance

Energy performance of currently used air-condition has been measured from actual equipment in case study building. These obtained data will then be used to calculate EER value. The EER value of air-condition can be calculated from COP value using power consumption and cooling capacity as presented in equation (1) and (2).

$$COP = \frac{Q_L}{E} \quad (1)$$

$$EER = 3.412 \times COP \quad (2)$$

When

Q_L is Cooling Capacity

E is Energy Consumption

Air-condition system currently used in case study building is split types air-condition. The total number of currently installed air-condition in the building is 291 units with 20,000 and 30,000 BTU sizing capacity. The specification of currently used and replacement air-condition in terms of EER value, energy and power consumption is shown in Table. 2 and 3 respectively.

Table 2. Specification of current equipment in air-condition system.

Size (BTU)	Installation year	Power (kW)	Energy (kWh/year)	Energy Efficiency Ratio (EER)
20,000	1994	3.53	6,77.6	5.07
	2008	1.99	2,865.6	8.53
30,000	1994	4.44	8,524.8	6.7
	2008	3.53	6,624.0	9.77

Table 3. Specification of newly renovate equipment in air-condition system.

Size (BTU)	Power (kW)	Energy (kWh/year)	Energy Efficiency Ratio (EER)
20,000	1.3	3,120	15.4
30,000	1.94	4,656	15.25

According to the Table, air-condition replacement has significant improvement in terms of EER value and requires less energy consumption at the same BTU size. This is because currently used air-conditions in the building are aging with more than 20 years of installation and the efficiency value is lower than standard limit for the education types building according to BEC.

The energy performance of air-condition replacement measure can be summarized in Table 4. From the table, it can be seen that power consumption in case of air-condition replacement can be reduced up to 317 kW and results in saving of 647 kWh per year.

Table 4. Energy performance of air-condition renovation measure.

Number of Air-Condition (unit)	291.00
Current Power consumption (kW)	920.25
Replacement Power consumption (kW)	647.95
Power Reduction (kW)	317.43
Annual Energy Saving (kWh/yrs.)	647.95

3.2. Economic Analysis

The economic analysis for air-conditioning renovation in this research will be done using two important parameters that can assert the feasibility of the project; discounted payback period and internal rate of return (IRR). Discounted Payback can be calculated using equation (3) and (4).

$$\text{Discounted Cash Inflow} = \frac{\text{Actual Cash Inflow}}{(1+i)^n} \tag{3}$$

$$\text{Discounted Payback Period} = A + \frac{B}{C} \tag{4}$$

When
i is Discounted rate
n is Period of cash flow (years)
A is Negative discounted cumulative cash flow
B is Discounted cumulative cash flow at the end of the period A
C is Discounted cash flow during the period after A

For the IRR value, it can be calculated using equation (5)

$$I_0 = \sum_{t=1}^{n} \frac{ES_t}{(1+IRR)^t} = 0 \tag{5}$$

When
I_0 is Initial investment
n is Project life (years)
ES_t is Annual energy cost saving from year 1 to n
IRR is Internal rate of return

Initial cost of the project including equipment and installation cost for all air-condition replacement in building is approximately 606,748 USD.
The calculation of energy consumption is based on current electric Thailand electric price at 3.98 THB/kWh or 0.121 USD/kWh (1 USD = 32.75 THB) and inflation rate at 2% per year according to Bank of Thailand inflation forecast. The result from economic analysis is shown in Table 5.
From the table, it shows that investment in building air-condition system replacement measure can achieve discounted payback period within 7.43 years with IRR value 14.06%.

Table 5. Payback period for air-condition renovation measure.

Year	Installation Cost	Energy Cost Reduction	Maintainance Cost	Net Present Value	Balance
0	606,748.40	0.00	0.00	-606,748.40	-606,748.40
1	-	92,126.91	4,442.75	85,964.86	-520,783.53
2	-	91,214.77	4,442.75	83,402.51	-437,380.97
3	-	90,311.65	4,442.75	80,916.14	-356,464.79
4	-	89,417.48	4,442.75	78,503.29	-277,961.28
5	-	88,532.15	4,442.75	76,162.34	-201,798.91
6	-	87,655.60	4,442.75	73,890.62	-127,908.28
7	-	86,787.72	4,442.75	71,686.28	-56,222.08
8	-	85,928.44	4,442.75	69,547.25	13,325.22
9	-	85,077.66	4,442.75	67,471.68	80,796.90

4. Conclusion

This paper proposed energy and economic analysis on air-condition renovated measure using building in Thailand as case study. The replacement of air-condition has been selected using COR and EER value within BEC standard. In terms of energy performance, air-condition replacement can reduce annually energy consumption by 647.95 kWh.

In terms of economic perspective, the renovation measure proposed in this study can achieve discounted payback period around 7.43 years with 14.06% IRR. This value is attractive for investor to invest into renovation project.

It can be seen that air-condition system renovation in existing building can achieve long-term benefit in perspective of improving overall energy efficiency and reducing annual energy cost with attractive economic parameter. The renovation methodology and result proposed in this research can be applied to other renovating projects to evaluate the feasibility and the renovation in low efficiency system.

5. References

[1] Energy Policy and Planning office (EPPO) 2016 *Energy Statistics of Thailand 2016* Energy Policy and Planning Office, Ministry of Energy of Thailand
[2] Ministry of Energy 2011 *Thailand 20-Year Energy Efficiency Development Plan (2011-2030)* Energy Policy and Planning Office, Ministry of Energy of Thailand
[3] *The Energy Conservation Promotion Act B.E. 2535,* 1992
[4] Department of Alternative Energy Development and Efficiency (DEDE) 2012 *Research and Development in the field of Energy Conservation and Renewable Energy in Thailand* Department of Alternative Energy Development and Efficiency, Ministry of Energy
[5] D. D'Agostino, B. Cuniberti, and P. Bertoldi 2017 Energy consumption and efficiency technology measures in European non-residential buildings *Energy and Buildings* vol 153 pp 72-86
[6] J. Yao 2018 Modelling and simulating occupant behaviour on air conditioning in residential buildings *Energy and Buildings* vol 175 pp 1-10
[7] T. Wu, B. Cao and Y.n Zhu 2018 A field study on thermal comfort and air-conditioning energy use in an office building in Guangzhou *Energy and Buildings* vol 168 pp 428-437
[8] K. Alutairi, G. Thoma, J. Burek, S. Algarni, and D. Nutter 2015 Life cycle assessment and economic analysis of residential air conditioning in Saudi Arabia *Energy and Buildings* vol 102 pp 370-379
[9] W. Thanuanram, N. Auppapong, P. Nupteotrong and D. Buayorm, 2015 The Energy Saving in Air Condition System of Thailand Building and Factories *Energy Procedia* vol 79 pp 859-864

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