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Lighting Retrofit Scheme Economic Evaluation

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Abstract

In this paper, two lighting retrofit scheme is simulated to evaluate the amount of saving that the commercial building owner would benefits. Simple payback period and net present value are the method used to qualify the retrofit scheme to be profitable or otherwise. The analysis includes the effect of electricity price, energy saving percentage, technology price and efficacy future values towards the economic return. The retrofit scheme presented only covers for the building that already has existing lighting equipment and complies towards the standard set by the international technical society. All variables and assumption are based on latest report by the world governing bodies and regulation.

Keywords: *Lighting Control Integration, Energy Efficiency, Payback period, Net Present Value*

1. Introduction

2016 is a challenging and difficult year for the global economy. The over supply issue of commodity and low market demand creates chain reaction to the business and manufacturing companies to sustain its operation. Operation downsizing and merging has become one of the popular method to survive against the global economy slowdown. Besides that, cost reduction activity is implemented across every corner of business to ensure its cost competitiveness and maintaining the profit margin over low market demand.

There are few sectors benefited from these cost reduction activity, and one of it is the cost reduction consultation firm. Many company choose to appoint a consultant to help them to restructure their monetary budget and increase their operation efficiency. Some consultation service focus on how to reduce utility bills through energy auditing and facility retrofit. Figure 1 shows the expenses breakdown of a typical commercial operation in United States.

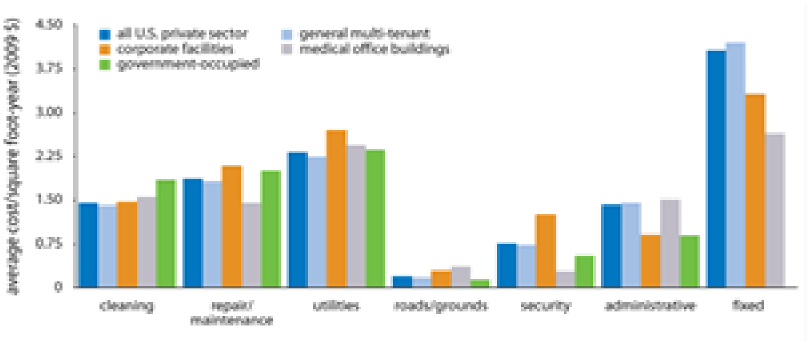

Figure 1. Expenses breakdown for commercial sector [1]

Utility bills contributes about 10-20% in average of the total operational cost of a commercial operation. Reducing the cost from utility bills can certainly help the company to compete in this challenging market. In some countries, the commercial building owners are

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obliged to perform energy auditting and saving. For example in Malaysia, under the Energy Commision, any building that uses more than 300,000 kW-h for 6 months consecutively must appoint an electrical energy manager to manage energy efficiently at their building. This regulation were commenced in 2008 as part of the nation's promises towards the international organization to reduce greenhouse gas emmision.

1.1. Energy Cost of a building

Energy cost can be reduced in many ways. By understanding the consumption behaviour of each load in a building, the energy consumption reduction can be strategize and plan. Table 1 shows electricity consumption by end use [2]. Figure 2 shows the average electricity consumption by end use in percentage from Table 1. Heating, ventilation and cooling (HVAC) consumed the most energy of a commercial building followed by lighting, refrigeration and office equipment. By choosing to retrofit and improve HVAC energy efficiency would lower the energy cost of the building.

Table 1. Electricity consumption (trillion Btu) by end use.

	Total	HVAC	Lighting	Refrigeration	Office equipment	Others
All buildings	4,241	1,384	724	670	557	769
Building floorspace (square feet)						
Below 50,000	471	135	77	96	62	101
50,001 to 100,000	654	224	110	103	87	129
100,001 to 200,000	647	220	119	92	94	122

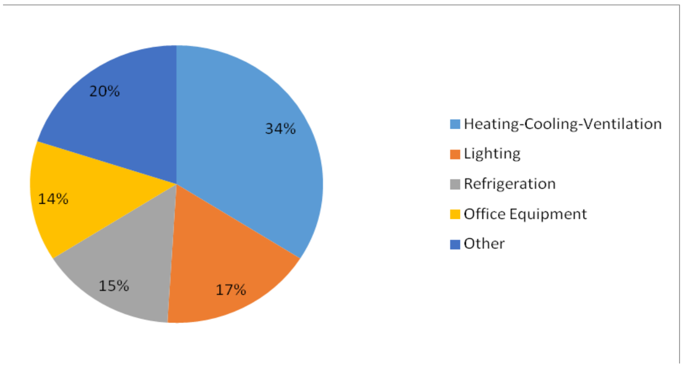


Figure 2. Average electricity consumption by end use in percentage

Besides HVAC, reducing lighting mathematically would lower the electricity bills. To reduce the lighting electrical consumption, the building owner can start with a simple awareness program. This is consider to be the first phase of energy efficiency practice because it requires minimum cost and time. The second phase is where the building owner need to splash some cash. To further reduce the electricity consumption from lighting, the lighting efficiency study must be perform. Based on the study, important data such as illuminance level, lamp hourly consumption, fixture, location, wall color, shaded object, window and frequency of usage can be determine. In the next section, the energy efficiency of the building through lighting system installation and lighting products is discussed. The cost of this installation then is compared to saving made over 20 years period.

2. Scope of Lighting Retrofit Scheme

Lighting system contributes about 20% of the total energy expenses in commercial building. There are many research article discuss about the possibility of managing the light efficiently through the use of sensor, timer, de-lamping and natural light. Intelligent lighting system in [3] clarified that the problem of implementing the intelligent lighting system is the actual wiring of the building is complex. Hence, adopting the same system to other office building is not possible unless the wiring configuration is identical. Furthermore, the sensing module to provide input to the controller is not cheap. The research mainly pointed out the advantage of the proposed system in terms of reliability and controllability that increase the overall system efficiency. CFL size T8 is used as initial lamp type before retrofit activity.

2.1. Integrated Smart Lighting Control Retrofit

There are 2 major lighting control strategies available. Smart Lighting Control is a light switch capable of remote operation through mobile apps in Android or iOS devices. A high specification switches offer better light control and features such as dimming, scheduling and integration. Daylight and occupancy strategy is not included for this paper because it involves major installation and renovation cost. In [4], the lighting control system that employ specific scheduling depending based on the application can save 25% of the energy consumed by the lighting or 15% from the total electrical energy of the building. Assuming that only switches and integrated system are invested in this project, while using existing lamp, the initial investment is calculated as follows:

$$P = A \times \sum s \quad (1)$$

P = Initial investment of Integrated Smart Lighting Control
A = Building area in ft2
s = Average integrated system lighting control price for 1 ft^2

The maximum Lighting Power Density (LPD) is used to estimate the number of switches for different type of buildings. Table 2 shows Three building size is considered based on Table 1.

Table 2. Maximum LPD for Different Type of Building [5]

Building Type	Maximum Lighting Power Density (W/ft^2)
Hospital	1.21
Manufacturing Facility	1.11
Office	0.90
Retail	1.40
School/University	0.99

2.2. Cost Estimation of Integrated Smart Lighting Control Retrofit

According to [7], the prices for top 10 lighting control switches are between 27 to 165 USD. The cheaper range controller, 27 to 70 USD is able to control the switches wirelessly via smartphone and timer. Middle price range 70 to 90 USD controller had additional dimmer while the higher price range product 90 to 170 USD is equipped with its own controlling panel that can be connected to multiple lights. As mentioned earlier, the retrofit strategy that involves major building renovation and installation is excluded. Figure 3 shows the average savings in % by control strategy [8].

2.3. Bulb Retrofit to LED

Troffer luminaire size T8 are the most common lighting products used in the building in Table 2. Assuming that the old lighting product is compact fluorecent lamp (CFL), the cost and initial energy usage will be based on CFL troffer luminaire size T8. The cost for this type of product includes fixture, reflactor and driver. Installation cost for CFL and LED is set to be the same.

$$L = A \times \sum h \quad (2)$$

L = Initial investment of LED Lighting Retrofit
A = Building area in ft2

h = Average LED system price for 1 ft^2
Product review in [6] shows that the lumens per watt of top 5 LED manufacturer is between 59 to 84 lm/Watt.

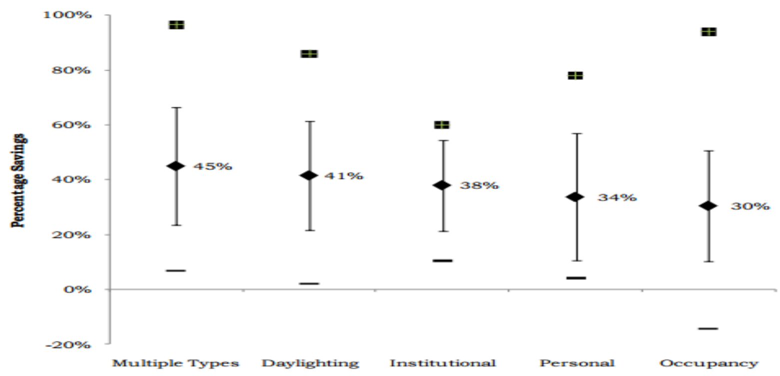


Figure 3. Average savings (%) by control type

2.4. Cost Bulb Retrofit to LED

According to [9] LED T8 tube (neutral white) luminous efficacy is 107 lm/W while CFL T8 tube luminous efficacy is between 87 to 94 lm/W. To find the energy saved from bulb retrofit, the lighting efficiency has to be known. The efficiency for this case is calculated as in Formula 2.

$$\eta = \frac{H}{683} \tag{3}$$

η= Light efficiency
H = Light efficacy
683 = Maximum light efficacy

$$S = P \times U \times \left[\left(\frac{100}{\eta 1}\right) - \left(\frac{100}{\eta 2}\right)\right] \tag{4}$$

S = Saving in Watt
P = Rated power in Watt
$\eta 1$= Efficiency of the CFL lamp in %
$\eta 2$= Efficiency of the LED lamp in %
U = Usage in hours

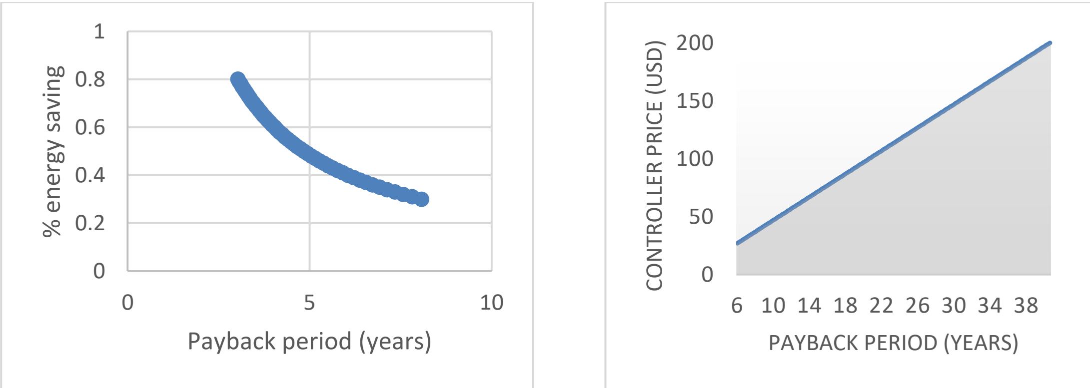
The issue in using saving formula derived from electrical appliance energy saving method is that the rated power is not known. Furthermore, the efficiency is calculated based on the maximum measured value of photopic vision and instead of the rated power of the bulb. Furthermore, the saving will not yield the power unit. Letting the rated power to be standard T8 bulb is not accurate because the efficiency of CFL lamp will become unity. A better option is to calculate how much less power is required by the LED to produce the same lumens value by the CFL bulb.

3. Result

3.1 Simple Payback Period

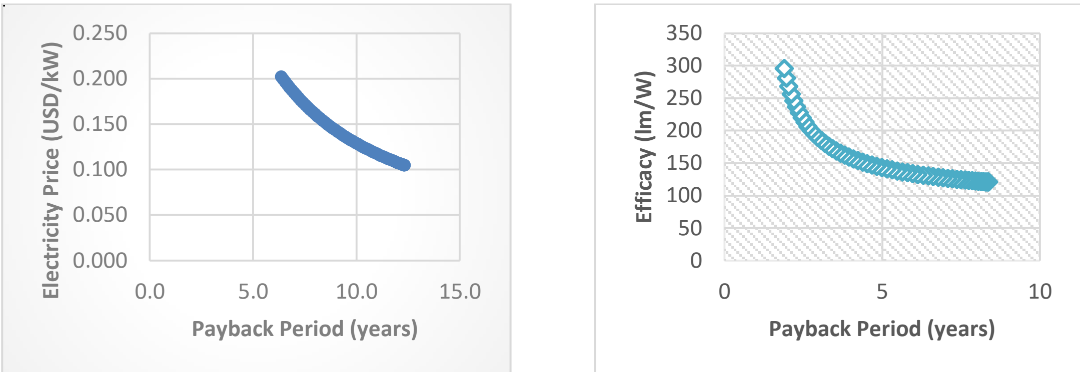
The most popular method to determine whether the investment is profitable or otherwise, simple payback period is used. Sales person usually uses this formula to sell their investment product. Figure 4 (a) shows the percentage of energy saving versus payback period while Figure 4 (b) shows the controller price versus payback period for Integrated Smart

Lighting control retrofit. For this scheme, the number of the controller is assumed to be half to the number of lights in the building. The investment may be lower when the controller is purchased in bulk. In Figure 4 (c) shows the electricity price versus payback period while Figure (d) shows LED efficacy versus payback period bulb retrofit. In this scheme, the number of bulb retrofits to LED is equal to the number of existing bulb. Only in Figure 4 (d) shows promosing result with return of investment around 2-10 years.



(a) (b)

Figure 4. (a) Percentage of energy saving & (b) controller price versus payback period for Integrated Smart Lighting control retrofit



(c) (d)

Figure 4. (c) Electricity price & (d) LED efficacy versus payback period bulb retrofit to LED

3.1. Net Present Value (NPV)

NPV can be used if the initial investment and annual profit is known. Equation 4 shows the general equation of NPV.

$$NPV = \Delta A \times PVF(d,n) - \Delta P \quad (4)$$

NPV = Nett Present Value
ΔA = Annual Return
PVF= Present Value Function
d= discount rate
n = number of investment year

3.2. Integrated Smart Lighting Control NPV

The controller price is set to the lowest value 27 USD. With a discount rate of 5.00% and a span of 5 years, the projected cash flows are worth $11,239.32 today, which is less than the initial $16,805.00 paid in order to begin. The resulting NPV of the above project is -$5,565.68, which means pursuing the above project may not be an optimal decision.

The economical benefit from lighting retrofit is minimal. Integrated smart lighting control price is not cheap. The return of investment from this scheme ranges from 3 to 8 years period. The bulb retrofit to LED has better investment potential. Reviewing the detail of the lighting retrofit proposal is mandatory to the building owner to ensure better saving yield.

3.3. Bulb Retrofits to LED

The LED buld price is set to the lowest value 10 USD. With a discount rate of 5.00% and a span of 10 years, the projected cash flows are worth $31,836.71 today, which is greater than the initial $22,687.00 paid. The resulting positive NPV of the above project is $9,149.71, which indicates that pursuing the above project may be optimal.

4. Conclusion

The method of economical potential of lighting retrofit does not count for new building. Looking from the positive side, the old switches and bulb can be recycled and sold for extra income. The lifetime of LED bulb 5 times longer than CFL bulb which reduces maintenance cost of the building. Most of the private sector building performs energy saving activity to adhere to the government authority and reduce their utility expenses. Besides that, reducing energy consumption translates into reducing greenhouse gas emmisson. Preserving environment is a noble act and priceless. Lighting control and LED technology advancement is promising and would benefit the end users through price and improved efficacy. With the fluctuation of commodity price, the electricity tariff is also unpredictable and the price trends moving north thus support the investment in lighting retrofit.

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