CASE STUDY FOR REPLACEMENT OF CONVENTIONAL LIGHTS BY LED LIGHTS

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Abstract

With the increment in the gap between the demand and supply of energy, various alternatives for decreasing the demand of energy are major concern for the various stakeholders. In order to decrease the energy demand by lighting various energy efficient lights are available in market. However it is difficult to convince the residents to change conventional artificial light sources, since lighting system is an essential part in the building which ensures the comfort, productivity and safety of the occupants in the buildings. Among the various Light Emitting Diode (LED) lights are termed as one of the most efficient energy saving lights which aims to save almost more than 50 % of energy demand than that of CFL lights with same power of illumination. Hence, this study is carried out to calculate energy saving percentage after replacing the conventional lights like florescent, mercury lights and other forms of conventional lights by LED lights. Additionally the study also was focused to evaluate feasibility of the replacement of lights by LED lights in terms of energy saving and return of investment. The research was carried out in building used by Agrotechnology and Food Science (AFSG) science group of Wageningen University in the Netherlands. The results from the study showed that almost 50% of the energy can be saved after replacement by LED lights with around 5 years for return of investment. However, factors like 1) Number of operating hours, 2) Price of lights, 3) Energy cost, 4) Labour cost for replacement and adjustment and 5) Number of replacement and adjustment per hour are the influential features that effects in the performance of various types of lights.

Keywords: Energy Consumptions, Energy saving, LED

1. Introduction

Sustainable Energy Development Strategies consists of three major technological changes: 1) energy savings on the demand side, 2) efficiency improvements in the energy production and 3) replacement of fossil fuels by various sources of renewable energy (Lund, 2007). The reduction of energy consumption can range from 36 to 86% depending on the measure(s) installed (Nilsson and Aronsson, 1993) and replacement of current lights by advanced energy efficient light could be one of the measure to reduce the energy consumption. Fluorescent and halogen lighting were regarded as more efficient lights with higher luminous efficiencies than incandescent lights (Beaupré, Boudreault et al., 2010). However with development in technologies, recently LED lights are regarded as most energy efficient and high luminous efficiency lights (Kavehrad, 2010).

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Usually, the combination of LED lights occupy less space and requires less energy for operation, compare to standard bulb type lamps they replace. The space saving and energy saving features of LED accelerates its popularity among designers and manufactures who are motivated for reduction in space and/or increment in the efficiency of light source used in their products (Klinke, Leising et al., 1995). LED lights are thus regarded as very promising lighting technology for energy saving lighting sources suitable for office and home lighting application (Schubert, Gessmann et al., 2005).

Hence this research aims to calculate the potential energy savings by changing fluorescent lights, mercury lights and halogen lights (current lights) to LED lights as an option for energy efficient lighting system. Furthermore, the major objective of the study is to evaluate feasibility of replacement of current lights by LED lights by analyzing energy saving percentage and Return of Investment (ROI) after replacement of lights.

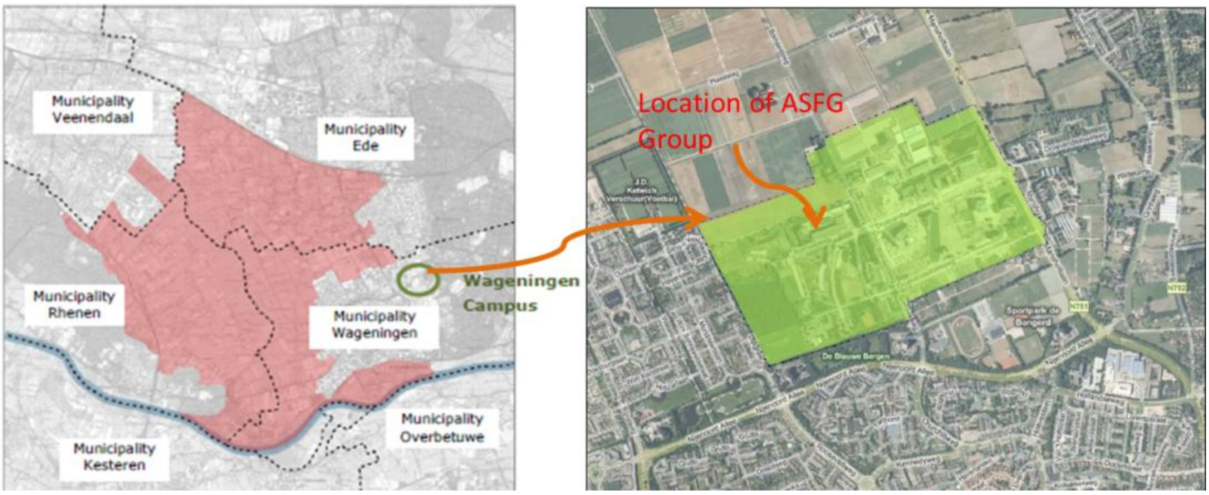

Fig. 1 Location of Wageningen Campus

2. Description of the Study Area:

Wageningen Campus with an area of 67.5 hectares is regarded as a centre for large number of applied research institutes. As shown in Fig. 1, the campus is situated in Wageningen municipality of the Netherlands. Wageningen Campus with sustainable buildings is regarded as one of the greenest and sustainable knowledge centres in the world that focuses on less energy consumption and sustainable energy production. There are five different science groups in the university which are differentiated on the basis of fundamental research and area of expertise. They are:1) Agrotechnology and Food Science (AFSG), 2) Animal Science (ASG), 3) Environmental Science (ESG) 4) Plant Science (PSG) and 5) Social Science (SSG). The study was carried out on 6 buildings under AFSG science group and buildings are named as are Axis X, Y, and Z, Qualitron 3, 4 and 5.

3. Methodology

3.1 Study Site and Case Study

Detail survey was conducted on each room of each building to ascertain the number and types of lights installed. Different types of lights and their respective number were surveyed to calculate the total electricity consumed by different types of lights in the buildings and also to identify the total amount of energy used by lighting. Function of each room was also listed in order to identify the requirement of lights according to the function of the room. This study only focuses on the change in existing lamps except existing LED lights, to LED lights having equivalent brightness (Lumens). Thus the data collected include the number of lighting fixtures and its corresponding operating hours.

3.2 Estimation of Electric Consumption

The annual energy consumption in a year was calculated based on following equation:

$$EC\ [Kwh] = \frac{N * W * OH}{1000}$$

Where; N= Number of lights, W= Power and OH = operating hours.

Approximately 3750 hours were estimated as operating hours in the buildings where total OH in a year was calculated based on the following estimations,

- Hours/day= 15
- Days/week=5
- Weeks/year= 50

Number of operating hours was obtained after interviewing students who are currently studying and doing thesis under AFSG department. They said that the office opens at 7am in the morning and closes at 10 pm. The department opens 5 days in each week from Monday to Friday. Approximately 50 weeks were considered as an opening weeks in a year after deduction of number of holidays in a year.

3.3 Energy Reduction Percentage

Energy reduction percentage (ERP) is calculated by application of equation below:

$$ERP = \frac{ECExisting - \text{ECRetrofitting}}{\text{ECExisting}} * 100\%$$

3.4 Energy Cost, Lifetime of Lamps and No. of Replacement per year

Cost of electricity is calculated by multiplying the total electricity consumption with the value 0.08 cents per KWh (Average energy price for Wageningen UR from Click Funds). Lifetime (LT) of different types of lights was calculated as shown in following formula.

$$LT = \frac{PLS}{OH}$$

Where: PLS= Projected Lifespan of different types of lights

After application of this formula, lifetime of different lights are determined. Based on the lifetime of different types of lights, no of replacement per year was calculated as shown in following formula.

$$Noofreplacement = \frac{No.\ of\ lights}{Life\ time}$$

3.5 Replacement Cost and Adjustment Cost

An interview with an electricity company that supplies electric lights and the manpower for replacement and adjustment was interviewed in order to identify the time and labour cost required for replacement and adjustment for retrofit of lights. Thus it is estimated that average €80/hours is used a value for labour cost. Based on this cost, replacement and adjustment cost is calculated by using following formula:

$$Replacement\ cost = No\ of\ replacement * (\frac{Labour\ Cost}{No\ of\ replacement\ per\ hour} + material)$$

$$Adjustment\ cost = (No\ of lights * \frac{Labour\ Cost}{No\ of\ adjustment\ per\ hour}) + materials$$

Note: Material here refers to the types of light fixtures, ballast, etc. required for changing the current light to LED lights. In case of replacement only light figure is required as a replacement where as in adjustment including light fixture, change in ballast, dimmer etc. might be required to change the current light to LED lights.

3.6 Return on Investment

Return on investment (RoI) estimates the amount of time required to recover the additional investment. For the calculation of RoI, total annual cost (TAC) required for each types of light including electricity cost(EC) and replacement cost is calculated. Then the difference in cost for existing lights and LED light is determined as saving cost. Finally RoI is determined by dividing adjustment cost by saving. The equational elaborations are provided in following equations.

$$Totalannualcostforeachlights(TAC) = EC + Replacemnet\ Cost$$

$$Saving\left[\frac{€}{h}\right] = TAC\ of\ LEDlights - TAC\ of\ existing\ lights$$

$$RoI[Y] = \frac{Adjustment\ Cost\ [€]}{Saving\left[\frac{€}{t*}\right]}$$

$$*\ refers\ to\ required\ time$$

4. Results

4.1 Lighting Survey

The results of the lighting survey showed that there were basically five types of lights installed in different buildings of the AFSG department. Types of lights installed in these buildings were fluorescent light (TL), high pressure fluorescent light (HTL), energy saving light (E.S.L.), halogen light and mercury light (Hg). In general most of the lights installed in the science group were 58 watt, 36 W and 35W TL lights and 18 watt E.S.L light. HTL lights were installed only in Axis Y building and other types of light (halogen and mercury) were installed in Axis X and Z buildings.

4.2 Comparison of Electricity Consumption by Existing Lights and LED Lights after Replacement

As presented in Fig. 2 outcomes of the calculation indicated that 14% of electricity is used for lighting in Axis X, 26% in Axis Y and 15% in Axis Z. In order to calculate the total electricity consumption, sum of kWh consumed by every types of lights in each buildings per year were analyzed and thus energy consumption percentage for lighting were determined after identification of total energy consumption for each Axis buildings. The electricity consumption in Qualitron buildings were not available due to which the electricity consumed by lighting in these buildings were not calculated.

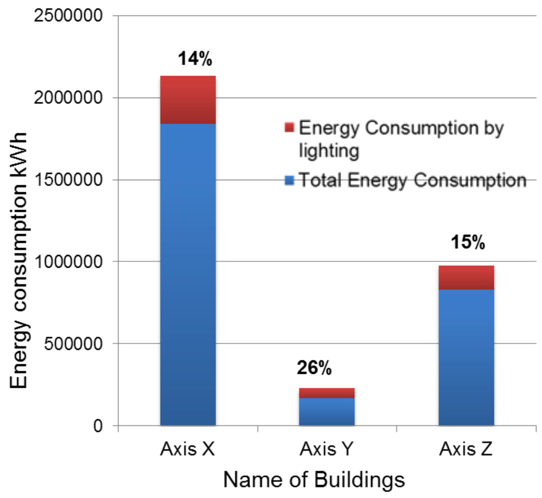

Fig. 2 Total electricity consumption by lighting in Axis buildings

Energy consumption by the LED lights after replacing the current lights was calculated to evaluate and analyze the difference in energy consumption by different types of lights in each buildings. This analysis was carried out to determine energy saving percentage after retrofitting current lights by LED lights. As presented in Fig. 3 the summary of the results showed that in average 57% in Axis X, 50% in Axis Z, 0%, 52% and 53% in Qualitron 3, 4 and 5 respectively of energy can be saved after replacement of all current lights by LED lights. In case of Axis Y the energy saving percentage was limited to 34% because the current lights installed in the building were HTL which consume less energy compared to normal TL lights. The cost and watt of these lights were confirmed by the light company Lindner who is supplier of lights and manpower related with lighting in AFSG.

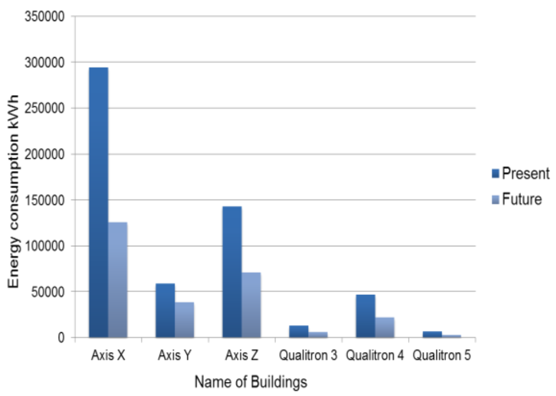

Fig. 3 Reduction in energy consumption after replacement of existing lights by LED lights

The existing electricity consumption by lighting in Axis X is approximately 208 MWh. As presented in Fig. 4, the largest fraction of this total energy was consumed by normal TL light. Energy saving light (E.S.L) was least energy consuming lights in the buildings. Results showed that if existing light i.e. TL, ESL, halogen and Hg lights are replaced by LED lights then 53%, 40%, 90% and 47% of respective lights' energy consumption can be saved. In case of Axis Y building, high pressure lights (HTL) were mostly used lights that used approximately 40 MWh of energy which is about 68% of total energy consumption.

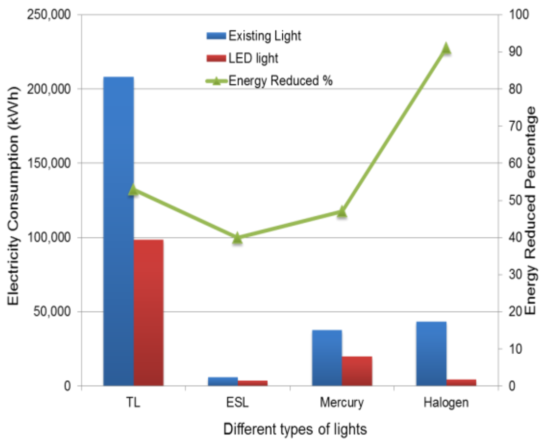

Fig. 4 Electricity Consumption by different types of light in Axis X building

As shown in Fig. 5, results indicated that 26% and 51% of energy consumption can be decreased after replacing HTL and ESL light respectively by LED lights. Axis Z building had a similar picture with Axis X. In this building also the highest energy consumption was used by TL lights. The approximate total energy consumption by this light was 120 MWh which was 85% of total consumption in the building. Fig. 6 shows that mercury lights were the second highest energy consuming lights which is followed by ESL and halogen lights. Thus if these lights are replaced by LED lights then the current energy consumption can be reduced to 52%, 46%, 90% and 40% in TL, ESL, halogen and Hg lights respectively. Fig. 7represents existing and future scenario about electricity consumption in Qualitron (Q3, Q4, and Q5) buildings i.e. before and after replacement of lights by LED lights. There were two types of lights installed in Q3 building. 70% of electricity was consumed by TL lights and remaining by Hg lights. If, these lights are replaced by LED lights then, about 52% of energy used by TL and 40%

by Hg light can be saved. In total 48% of energy consumption can be reduced in Q3 building. In case of Qualitron buildings, Q4 and Q5, only TL lights were installed in these buildings. Hence if these lights are replaced by LED lights then about 52% and 53% of total energy consumption can be saved in Q4 and Q5 respectively.

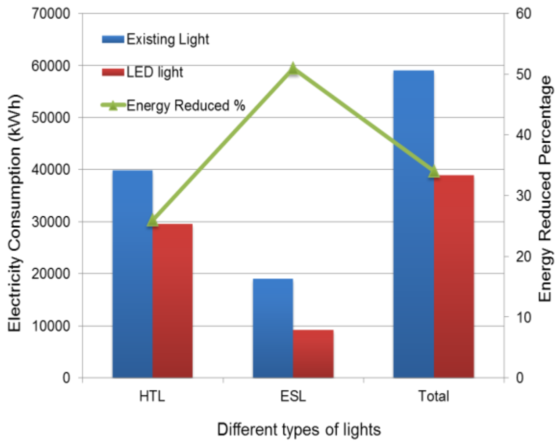

Fig. 5 Electricity Consumption by different types of light in Axis Y building

4.3 Investment for replacement and adjustment for LED lights and Return of Investment

Fig. 8 and 9 represent the results which specify investment for total maintenance cost required for replacing LED lights and RoI. Furthermore these graphs shows that there is a profit after replacement of lights by LED lights including replacement, adjustment and electricity cost. Investment required for installation of LED lights as adjustment cost and total Return on Investment (RoI) are also graphically presented in these figures. At present in Axis X building in average about 40,300 euros were required/spent for replacement and energy cost of current lights. If all types of lights in this buildings are replaced by LED lights then total maintenance amount will be reduced to 14,409 euros that will help to make a profit of approximately 25,900 euros per year. However in order to replace the existing lights approximately 117,200 euros are required as an investment cost and this remarkable amount will be returned as a profit after 4.5 years. Axis Z had a similar picture with Axis x with RoI of 4.8 years. The adjustment cost for LED light in this building was approximately 55,000 euros and profit in maintenance cost after replacement was about 11,600 euros (TMCurrent= approx. €20,000 and TMLED= approx. €8,500). Nevertheless Axis Y had different scenario. Since lights installed in this building were HTL which are regarded as most energy efficient lights after LED lights, energy consumed by lighting was already comparatively low in respect to other AFSG buildings. Thus in this building even RoI of LED light after replacing ESL was low (6.3 years), due to influence of HTL which were highest installed lights RoI for replacing these lights (17.5 years) increased the RoI for whole building to 10.4 years.

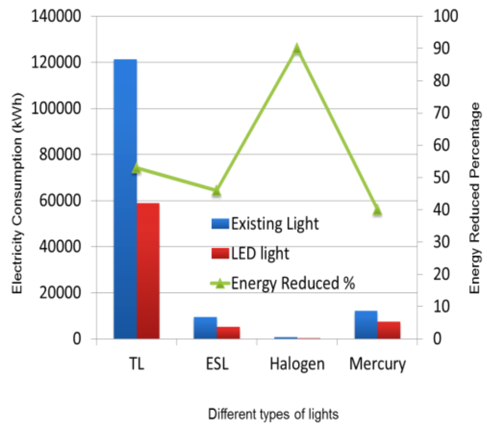

Fig. 6 Electricity consumed by different types of light in Axis Z building

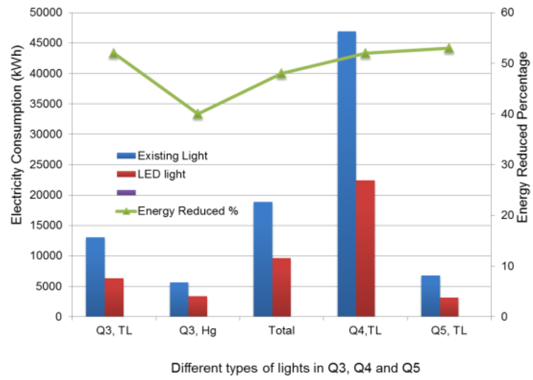

Fig. 7 Electricity Consumption by different types of light in Qualitron 3, 4 and 5 buildings

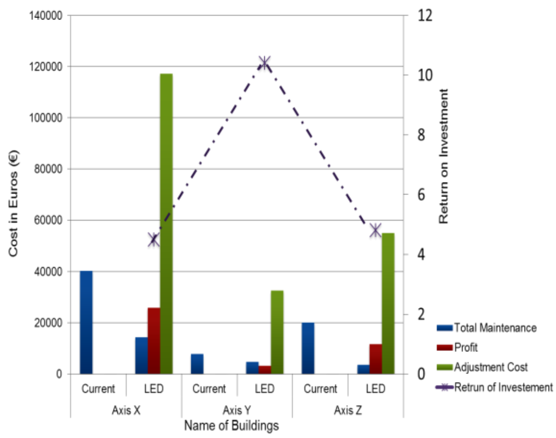

Fig. 8 Comparison of investment and Return of Investment in Axis buildings

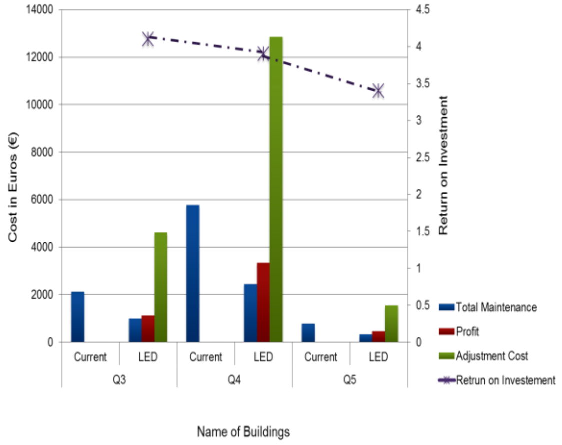

Fig. 9 Comparison of investment and Return of Investment in Qualitron buildings

In case of Qualitron buildings, results revealed that all buildings Q3, Q4 and Q5 had similar outcomes for Return on Investment. RoI of Q3, Q4 and Q5 were 4.1, 3.9 and 3.4 years respectively. Since numbers of lights in these buildings were comparatively lower than Axis buildings as these buildings were used as store, it can be predicted that the investment cost remained lower in these buildings. TM for current lights in Q3 was calculated as approximately €2110 euros which was €1121 more than total maintenance cost for LED lights. For adjustment of LED lights in order to replace existing lights about 4,600 euros would be required. In Q4 after replacement by LED lights approx. €2,400 could be a profit amount (TMCurrent= €5,764 and TMLED= €2,436) with an investment of approx. €12,900 as adjustment cost. Q5 had least numbers of lights installed in the buildings. Thus this building has least maintenance and adjustment cost. Total maintenance cost for LED light is approx. €300 which is approx. €450 less than TM of existing/ current lights and the adjustment cost for LED lights that are to be installed in this building is approx. €1,500.

5. Discussion and conclusion

5.1 Electricity Savings after Replacing Different Types of Lights by LED Lights

Results from the data analysis as presented in Fig. 10, under preferred condition and assumptions, confirm that electricity saving in different types of lights is not directly related to numbers of lights installed in any buildings. It is rather based on different types of lights that are installed for lighting. The following paragraphs are provided as an explanation to prove these arguments.

The results concluded that if normal fluorescent TL lights are replaced by LED lights then in average 51-53% of electricity consumption can be saved. However for the HTL lights, the energy reduction percentage is limited to 25% in average. The replacement of halogen lights by LED lights are most economical investment since the energy consumption can be reduced by 90% and this percentage was similar/same in all the buildings where these lights were installed. Furthermore if mercury lights are being replaced by LED lights then electricity consumption percentage can be decreased from 40 to 45%.

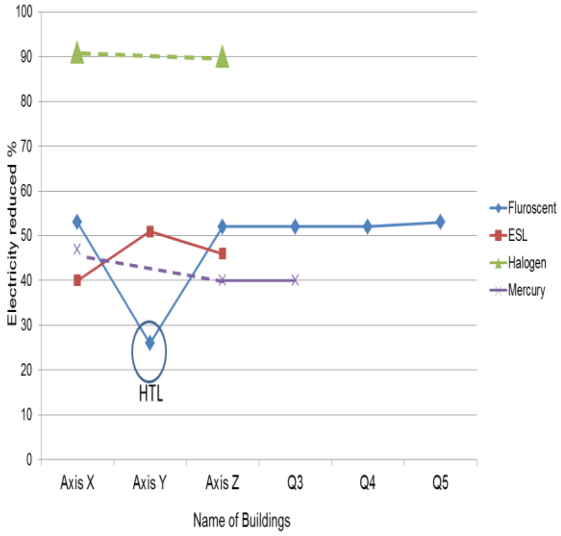

Fig. 10 Results that indicate energy saving percentage are based on types of lights

The results indicate that there is large potential to reduce the amount of electricity used by different types of lights after replacing these lights by LED lights in AFSG buildings. In average about 50% of energy can be reduced in every buildings if all lights are being replaced by LED lights except Axis Y building. Similar result and target was set by Plant Science Group for replacement of lights. As mentioned earlier the results thus suggest that energy reduction is based on types of lights installed rather than number of lights installed in a building.

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5.2 Relation of Return on Investment and Different Types of Lights

It is predicted that installation of LED lights is economical in terms of energy saving as well as in monetary values. This is expected since the replacement and adjustment interval or cycle for LED lights is comparatively lower than other lights. Similarly since the electricity consumption is lower than other lights, energy charge is also relatively lower than any other types of lights. According to the studies and results under per set Fig. 11 Comparison of Return on Investment (RoI) for replacement of different types of lights

conditions and assumptions installations of LED lights can be regarded as beneficial investment for AFSG. For most of the lights RoI is less than 8 years. For example, in most of the buildings RoI for normal TL lights is less than 4.5 years and for halogen lights, it is even less than 4 years. However, since HTL is energy efficient lights, results showed that these lights are not to be replaced immediately because these lights' RoI is more than 16 years. RoI of different types of lights installed in different buildings of AFSG are explained graphically in Fig. 11.

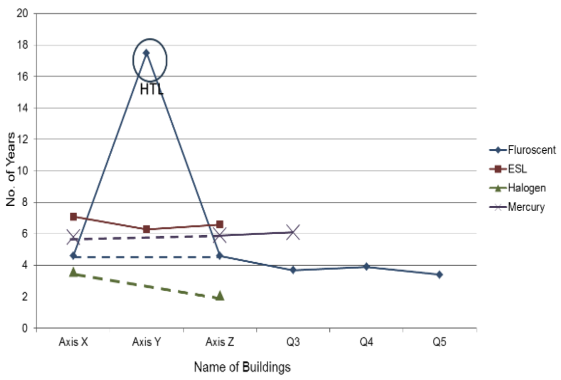

Fig. 11 Comparison of Return on Investment (RoI) for replacement of different types of lights

5.3 Factors Influencing Return on Investment

This study has identified four major factors influencing the Return of Investment after installation of LED lights by replacing current lights. These factors are: 1) Operating hours, 2) Energy price, 3) Installation price and 4) Energy reduction percentage after replacement. The first three factors were also identified by other studies as explained in Di Stefano (2000). The number of operating hours are case specific without any influence of external forces whereas cost of energy and installation price (including cost of light fixtures and labour cost) are affected by market price and government rules) (Di Stefano, 2000). Thus, there will be variation in results if similar studies are carried out in future.

The science group has higher number of operating hours. It might be due to lab works and computer rooms for writing research for thesis students. This assumption helped to lower the numbers of years for RoI. Thus lower RoI of different types of lights is affected by assumptions in numbers operating hours because higher the operating hours there is chances of decrement in RoI. In contrast, price of energy fluctuates in respect of time, government policies and energy Supply Company. The demarcation of lights fixtures price and labour cost are also allocated and changed by market chain that keeps on changing with respect to time and development of technologies. These alterations changes the amount of investment required for installation of LED lights and hence it directly effects on RoI.

Fig. 12 is a graphical explanation which demonstrates the relation between RoI and energy reduced percentage. This study revealed that these two factors have reverse relation. With the increase in energy reduced percentage there is decrement in number of years required for RoI. For example the energy reduction percentage in Q5 will be 54% with RoI of 3.4. On the other hand energy reduction percentage for Axis Y will be 34% with RoI of 10.4 in average. These explanations and examples prove that there is opposite relation of RoI and energy saving percentage with consideration of factors that affect RoI and the results supports this conclusion.

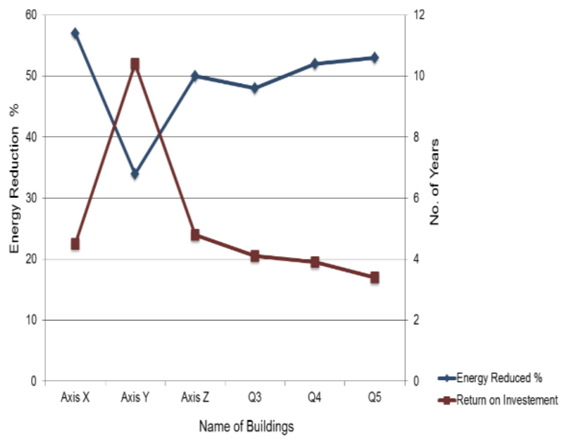

Fig. 12 Illustration of Relation between RoI and energy saving percentage

5.4 Conclusions

The major objective of this study was to evaluate whether replacement of current lights by LED lights in AFSG buildings is feasible. The feasibility was based on energy saving percentage and RoI after replacement of lights. The results from the study concluded that replacement of current lights by LED lights are feasible since, the average electricity consumption will be reduced to more than 50% and RoI for these buildings is less than 5 years. In this study one time survey was carried out during the research period which might affect results related with types of lights because the period is about four months and during this period there are possibilities that some types of light might have been replaced due to damage. Some other major factors that affected this study are: 1) Number of operating hours, 2) Price of lights, 3) Energy cost, 4) Labour cost for replacement and adjustment and 5) Number of replacement and adjustment per hour. These assumption are primary based on the case and conditions that are available and influence the case. Thus these are case specific and might be/ will be changed in future or other studies which might produce different results and scenario in future.

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