# Energy Saving in Governmental Educational Buildings: Case Study

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**Abstract –** *The Global warming and other environmental issues have stimulated researchers to explore and implement methods to achieve energy savings. In this paper, a case study is presented to save energy in an educational building. Two methods are implemented: 1) Replacement of the compact fluorescent lamps by light-emitting longitudinal lamps (LEDs); 2) Smart energy control via the installation of motion, heat, sound and light sensors. The amount of energy savings is calculated in Egyptian pounds per annum. The amount of reduction in CO2 emissions was also included. The luminous intensity is evaluated before and after replacement of the fluorescent lamps using the DIALux program. The practical installation of the proposed installation was conducted on a lecture's hall and the dean's office. A model of energy saving was implemented in Proteus with an Arduino platform. The model incorporated all the above sensors with different scenarios of operation. The model study revealed that an energy saving of 21.8% can be achieved. The total energy savings via the two methods was found 41.8 % and the payback period is about three years.*

***Key Words*:** Electrical Energy, Energy Saving, LED Lamps, Lighting, Luminous Intensity, LM35, LDR, PIR.

## 1. INTRODUCTION

Since electricity is used in all aspects of life the world without electricity is unimaginable, thus the need for the electrical energy is continuously increasing. For instance, the production of electric energy in Egypt has increased from 57.8 billion kWh in the year 2000 to 171.9 billion kWh in 2018 [1]. However, the production of electricity diversely influences the environment globally and locally [2-3], and hence the human health deteriorates [4]. In order to alleviate the environmental influences of electricity generation, two parallel paths were taken by the power engineers. These are the growth of renewable-energy-based systems and the attempts of available energy savings, as much as possible. Renewable energy sources provide an environmentally-friendly solution for energy production but still their installation costs are rather high [5-6]. Here, it comes the role of the other option, (Energy Saving).

The energy saving concept implies the minimization of the amount of energy required for a certain purpose with achieving the same goals. For instance, a significant part of energy is used in heating and/or cooling of homes, offices and commercial buildings. With the proper design of such buildings and good insulation, the amount of energy needed is significantly reduced and hence the total system cost [7-8]. There are many possible ways for saving the electrical energy that lies in three categories which are the proper design; the efficient/economic use and the updating with the technology advances. Many research works were carried out in order to explore and apply methods for the energy savings in buildings [9-13]. A case study for energy saving in Malesia is presented [9]. It focused on the lighting system of the Faculty of Technical and Vocational Education. The authors showed that substituting the fluorescent and incandescent lamps by the Light Emitting Diode (LED) lamps saves energy from 30% to 80%.

In Greece another study was done on some people about, energy use the data used in this study was collected through a structured questionnaire. The poll was unveiled during the spring of 2016 in the city of Athens. 451 people answered. The questionnaire included three parts: (a) the characteristics of the building, (b) The behavior of the occupants, and (c) the socio-demographic profile of the occupants of the dwellings. The analysis of the main components was used to identify behavioral patterns (components) for occupants of dwellings [14].

Abrol et al [10] developed data-enabled models of resident thermal preference and unregulated apartment temperatures. The developed models were used to evaluate the potential of energy saving by the proper design of cooling systems. The outcomes of their research show that that there are three factors that influence the amount of energy savings: building's physical characteristics; thermal preferences of the residents; apartment's geographic orientation. An example of building was considered in the study and a (28%) of savings was obtained.

Temperature control is studied by the Buildings management system [11] for the purpose of energy saving. Explores the work in [11] HVAC control methods and the potential impact they may have on the comfort of the population, with advanced control methods, savings of (18.8%) have been achieved. An automated blinds system is applied [12] to demonstrate the saving of electrical energy and at the same time maintain the same comfort level of and the adequate amount of lighting. The results of the project showed that the automated system saves about (50%) of the energy, compared to the manual system. Zonal heating control is implemented in [13] for a typical Canadian house. The set point temperature is determined by the residents and the control system measures the indoor and outdoor temperatures. Based on these measurements, a gas furnace is turned on and off. The results proved that the zonal heating control can save up to (36%) of the energy.

Continuing to these efforts, this paper presents a case study for an educational governmental building that is the Faculty of Industrial Education, Helwan University, Cairo, Egypt. Section II presents a description of the electrical loads of the faculty building under the study. Section III presents the results of energy saving by replacing compact fluorescent lamps with light-emitting longitudinal lamps (LED). In Section IV, the results of energy saving by using sensors and smart control, is presented. Section V provides the overall conclusions of energy saving using the two proposed methods.

## 2. Energy saving using LEDs
## A. The Electrical Load

The faculty building consists of four floors. Most of the workshops with heavy equipment are in the first floor. The other three floors contain laboratories and lectures halls. All the electric loads/equipment of faculty building were surveyed for each floor and the results are shown in Fig. 1. The total connected load is (365 Kw) and the major part of it is the machines and equipment (48.6 %) where all the workshops and laboratories are included. The lighting loads are about (100kW) which represents (27.4%). The monthly energy consumption of the building for one year during 2017 was recorded from the paid electricity bills and the data is shown in Fig.2. It is clear from Fig. 2 that the maximum load is on July. This is mainly due to the air conditioners as the temperature is the highest and during this month the students are performing summer training where most of the labs and workshops are busy. The total energy consumption throughout the year is (621621 KWH).

There are two types of luminaries that are found in the building. Both luminaries use fluorescent lamps. One luminary has a 120-cm, 36-W lamps and the other contains 60-cm, 18-W lamps. Each lamp uses an electromagnetic ballast of 10-W rating, roughly. The quantities of the lamps are given in Table. 1, that most of the lamps are of 120-cm and 36-W type.

The total power of the lamps is

$$(448) \times (18 + 10) + (1896) \times (36 + 10) = 99.76\text{KW}$$

It is worth to mention here that the operational hours of lighting are 10 hours per day, for 26 days per month and total of 12 months. Thus, the operational hours are

$$(10 \times 26 \times 12) = 3120 \text{ Hours}$$

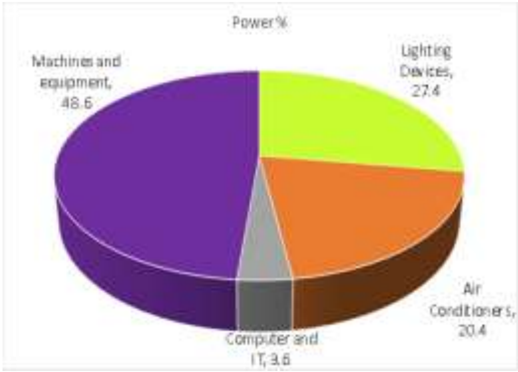


**Fig – 1:** Load Distribution of the faculty building.

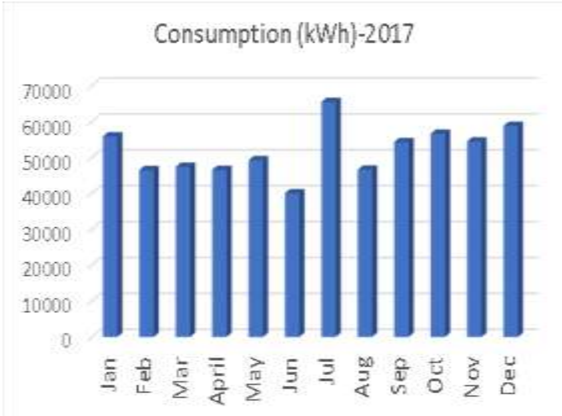


**Fig – 2:** Monthly energy consumption of the building during 2017.

**Table -1:** Quantities of the fluorescent lamps distributed among the building floors.

| Fluorescent Lamps | Quantity | | | | |
|---|---|---|---|---|---|
| Type-Power | Ground Floor | 1st Floor | 2nd Floor | 3rd Floor | Total |
| 60 cm – 18 W | 150 | 50 | 0.0 | 248 | 448 |
| 120cm – 36W | 520 | 300 | 700 | 376 | 1896 |

## B. The Proposed Lighting Installations

The proposal is to replace the fluorescent compact lamps (FCL) by LED lamps because of their documented high efficiency and ability of energy saving, albeit their relatively higher prices [14-15]. Every FCL is substituted by a LED lamp, i.e, the total number of lamps and luminaries stay the same. Quantities of lamps and the power calculations are given in Table. 2.

Based on Table 2, the following calculations are done. The diversity factor is taken as 1.5 according to the recommended values in [16].

Amount of power savings for the total connected load $=(99.76) - (38.16) = 61.6$ kw

Maximum amount of power savings $= \frac{(61.6)}{(1.5)} = 41.06$ kw

Amount of energy saving per year

=Maximum amount of power savings ×Operational hours

$$(41.067 \times 3120) = 128129 \text{ kw}$$

Currently the tariff of electricity in Egypt is (0.90) LE for up to 500 kWh for senior sector subscribers [24-23].

The Energy Saving in Egyptian Pounds per year

$$(128129 \times 0.90) = 115316\text{LE}$$

**Table -2:** Existing and Proposed Number of lamps and their power calculations.

| Current Situation | | | Proposal I | | |
|---|---|---|---|---|---|
| Type | Quantity | Power (kW) | Type | Quantity | Power(kW) |
| FCL, 120-cm, 36 - W, Magnetic Ballast T8 | 1896 | 87.216 | LED Longitudinal Lamp, 120 -cm, 18- W | 1896 | 34.128 |
| FCL, 60-cm, 18 - W, Magnetic Ballast T8 | 448 | 12.544 | LED Longitudinal Lamp, 120 - cm, 9- W | 448 | 4.032 |
| Total Power (kW) | | 99.76 | | | 38.16 |

The price of 120-cm, 18-W LED lamp is 100 LE while the price of the 60-cm , 9-W LED lamp is 80 LE. The purchased number of lamps should be greater than the actual number needed for having spares in the inventory in case of the malfunction of lamps. Taking a spare percentage of 10 %, the total number of lamps for the 120-cm, 18-W LED lamp should be: $(1896 \times 1.1) = 2085.6 \approx 2100$ Lamp

For the 60-cm, 9- W LED lamp, the total number is:

$$(448 \times 1.1) = 492.8 \approx 500\text{Lamp}$$

Then, the total cost of lamps is:

$$(2100 \times 100) + (500 \times 80) = 25000$$

The payback period in years = Total cost of lamps/Energy Saving in LE

- $= \frac{(250000)}{(115316)} = 2.17 \approx 2$ Years and 2 Months

It is known that a reduction or saving in electrical energy yields a reduction of the emission of Carbon Dioxide gas ($CO_2$) and hence the environment improves. According to the Environmental Protection Agency, USA, and using the Greenhouse Gas Equivalencies Calculator that is available at their website [17], a 128129-kWh saving in energy yields a reduction of $CO_2$ by 95356 kg. Finally, the percentage of expected savings after installation of the LED lamps is calculated as:

% Savings = 100 × Amount of energy saving per year /Total Energy Consumption per year $= \frac{(100)\times(128129)}{(621621)} = 20.6\%$.

### C. Practical Lighting Installations

As stated in Section III, the proposed solution is replacing the FCLs by LEDs Two places were selected to install and test the validity of the proposal: the lecture's hall B204 and the Dean's office. In addition to energy savings, the LED lamps have other merits compared to the FCLs. The CFL has disadvantages [19] such as: high total harmonic distortion, greater than (100%) and up (171%); low true power factor, around (0.58) (on average). Compared to LED lamps, the luminous efficiency (lm/W) of FCL is low, (51.2%) while for the LED is (83.3%) [20]. On the other hand, the maintenance cost of LEDs is significantly low due to the long-life span which is greater (50000) working ours [21].

Before installing the LED lamps, the luminous intensity in the lecture hole B204 was evaluated using the DIALux software [22]. Twenty-four luminaries were entered with each luminary having 3 lamps as per the above description. The luminous intensity distribution is depicted in Fig. 3. The maximum intensity is obtained at the middle of the hole, (320 lumens). In the front corners, the luminous intensity is minimum, 200 lumens.

Both values do not satisfy the illumination requirements (500 lumens) according to the Egyptian Code (Code No. 308) of lighting [18]. After the installation of LEDs, the luminous intensity has reached 560 lumens as shown in Figure 4 at most of the working plane. The obtained minimum on the corners was (350 lumens). The simulation results show that the LED lamps have significantly improved the luminous intensity with the same number of lamps.

The same luminaries were used and only the lamps were replaced. The voltage, current and power factor were measured before and after the replacement. Also, the luminance was measured.

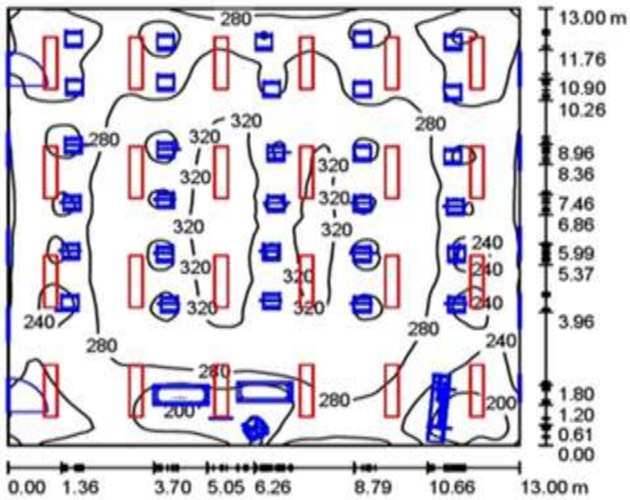


**Fig – 3**: Luminous intensity of B204 before installation of LEDs.

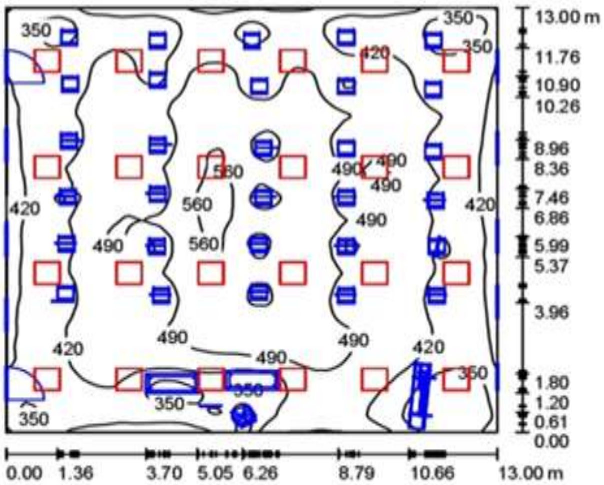


**Fig – 4**: Luminous intensity of B204 after installation of LEDs.

## C.1. Lecture's Hall B 204

Before installation, the measurements are recorded in Table. 3 and the measuring instruments are depicted in Fig.5. From Table 3, the drawn power is$(220) \times (24) \times (0.6) = 3168kw$

**Table-3**: Recorded Measurements before the replacement of lamps-204.

| | |
|---|---|
| Voltage (V) | 220 |
| Current (A) | 24 |
| Power Factor | 0.6 Lag |
| Luminance (lux/m) | 317 |

After the replacement, the measurements are given in Table 4 and the measuring instruments are displayed in Fig. 6. From Table 4, the power is (858 W).

This yields a power saving of$(3168) - (858) = 2310w$ The energy saved per is:

The money saving is : $(7207) \times (0.90) = 6486$ LE

**Fig – 5:** Measurements before installation-B204.

**Table-4**: Recorded Measurements after the replacement of lamps-B204.

| | |
|---|---|
| Voltage (V) | 220 |
| Current (A) | 24 |
| Power Factor | 0.975 Lead |
| Luminance (lux/m) | 585 |

**Fig – 6**: Measurements after installation-B204.

## C.2. Dean's Office

The Dean's office consists of 8 luminaries with each luminary contains 2 lamps. The old lamps are of the type: FCL, 120-cm, 36-W. They are replaced by LED longitudinal 120-cm, 18-W lamps. The same measurements were repeated and the results are given in Tables 5 and 6 and Figs 7 and 8.
The power before installation is (567.6 W) , while after the installation is( 198 W) . Energy saving is:

$$\frac{(567.6 - 198) \times (3120)}{(1000)} = 1153 \text{ KWh}$$

It implies a money saving of 1038 LE per year. The total money saving per is:$(6486) + (1038) = 7524$ LE

If a 100 lamp were purchased with a 100-LE each, the payback period is:

$$\frac{100\times100}{7524\times0.67} \approx 2 \text{years}$$

$$(2310) \times (3120) = 7207kw$$

**Table-5**: Recorded Measurements before the replacement of lamps-Dean's office.

| | |
|---|---|
| Voltage (V) | 220 |
| Current (A) | 4.3 |
| Power Factor | 0.6 Lag |
| Luminance (lux/m) | 250 |

**Fig – 7**: Measurements before installation-Dean's office.

**Table-6**: Recorded Measurements after the replacement of lamps-Dean's office.

| | |
|---|---|
| Voltage (V) | 220 |
| Current (A) | 1.0 |
| Power Factor | 0.9 Lead |
| Luminance (lux/m) | 550 |

**Fig – 8**: Measurements after installation-Dean's Office.

## 3. IV Smart Control Energy Saving Model Overview

The idea of the Arduino device appeared in 2005 in the Italian city of Ivrea, where Masemo Banz, youthrough cooperation with David kwartelis and Cynloka Martinu launched the project of (Arduin of Ivrea). This project was named after the most famous historical Character in the city. The objective of the project was to create an accurate development of controllers which has 100% open source. This project included creating a programming development environment of accurate controllers Integrated Development Environment. It would be free at the same time it also included making small Development Boards which have simple cost that Reaches about $ 27 now so technical students and Amateurs can afford , till the year 2013 more than (700000) Development Boards have been Loaded Arduino. In English (Arduino) is an electronic Board which consists of an open electronic circuit whit an accurate controller which is programmed via computer. It is designed to facilitate the use of interactive electronics in multi specialization projects like economizing the electrical energy conservation. The Arduino is mainly used in designing the interactive electronic projects and the Projects that aim at building different environmental sensors like the degrebs of light, motion, sound, temperature, etc. The Arduino can be connected to different programs on the personal computer. It depends on the open programming language source (processing). The Arduino programming codes are similar to the 'C' language which is considered as the easiest programming languages that are used in writing accurate controllers programs. Figure 9 shows a simplified drawing of the models. It is a group of nodes and every nodes represents a group set of sensors. It can be put all the above mentioned sensor sing deuces together with different scenarios of The process through controlling with an automatic button for the system's. The strength of light can be controlled by using the light sensor the eqecinc tans can be controlled by the heat sensor by the suitable amount as the place ventilation, this model is distinguished by reducing the standard of the power consumption and this makes it very suitable for save energy. [30-40] by doing the work designed by it as shown in figure 9 Model wire sensor networks.

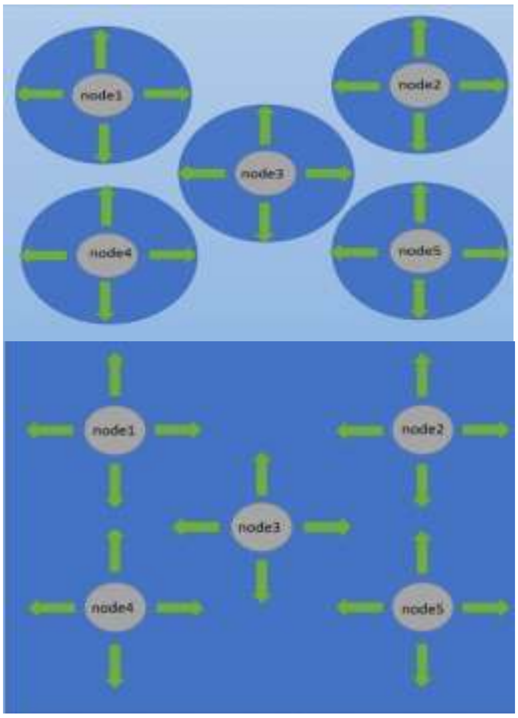


**Fig – 9**: Model wire sensor networks.

## 4. Method of work in the form by Arduino Uno Controller

In this project is used (Uno r3 it's an Arduino Board) it's selected to be the control unit in project, which it's used as a motion control board. This system used Arduino controller platform with ATMEGA 328 core. The ATMEGA

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 09 | Sep 2019 www.irjet.net p-ISSN: 2395-0072

328 is a single chip controller which is created by Atmel and it belongs to MEGA AVR series. The microcontroller is flashed with GCODE interpreter firmware written in optimized 'C' language, Programming will be made for the simulation model that builds on how to saving electricity, It shown in figure (10) Prototype of project in Proteus and Fritzing software [41].

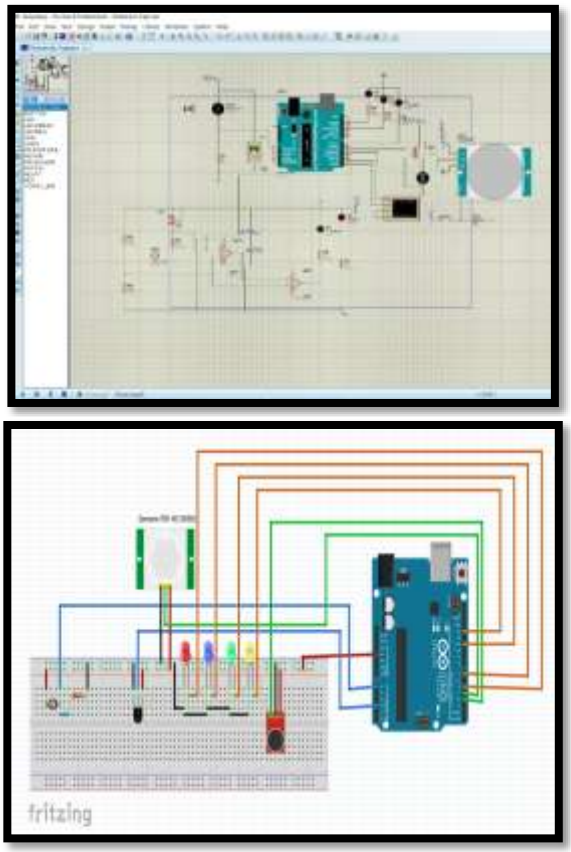


**Fig – 10**: Prototype of project in Simulation proteus and fritzing software

## Total system work

The whole system work the control unit is connected to the motion, sound, heat and light sensors and A condition to activation the system of motion of sound or both was put, the light system can be work through Standard S/Levels according to the light intensity inside the Place and Running the Fans on Electricity through Several Speeds depending on the temperature in its place. This system needs the rationalization of electric power consumption inside the place according to the motion conditions via Proteus by using Arduino to limit the person mistake of his power consumption to save energy. The system consists of the following:

## LDR [Light Dependent Resistor]

The aim of using light sensor in this project is to control the lighting intensity of the room so that it can be increased or reduced in the case of a person in this room or not [26].

## LM35 [temperature sensor]

The aim of using the temperature sensor in this project is to control the room temperature so that it can be increased or decreased in the case of a person in this room or not and thus increase the speed of the fan or air conditioner or vice versa [27].

## PIR [motion sensor]

The purpose of using the motion sensor in this project is to control the activation of the system inside the place where the condition of activating the system is the presence of a person inside the room and if the person moves within the sensitive range, the condition is activated by connecting the sensor with the controller and setting the movement condition to activate the lighting system, the system is shut down [28].

## MIC [Sound Sensor]

The purpose of using the sound sensor in this project is to control the activation of the system within the place where the state of activation of the system is the presence of a person inside the room and if the person talking or using anything that sounds in a sensitive range, the condition is activated by connecting the sensor with Controller and condition is status of the sound to activate the lighting system and all the systems in place and if the condition is not met, the system is shut down [29].

## System Summary

| Scop Work | Proposal I | Proposal II |
|---|---|---|
| Annual Savings | 57720 kwh | 115440 kwh |
| % *Savings* | 11.1 % | 25 % |
| Annual savings per pound | 51984 LE | 103896 LE |
| The payback period in years | *2* Years and 3 Months | *1* Years and 2 Months |
| % Savings in energy yields a reduction of CO2 | 3.1 Tons | 62.3 Tons |

It shown in Table (7), Calculations of Methods Smart Control Energy Saving. The case study was done on the Faculty building.

**Table-8**: Faculty building calculations

| | |
|---|---|
| Building Faculty area=2390 $m^2$ | Space Coverage node= 10 $m^2$ |
| Node number required=$\frac{2390}{10}$ = 239 nodes | Price of nodes=500 LE |

The Faculty building consists.

## <u>Proposal I</u>

The operational hours are$(10 \times 26 \times 12) = 3120$ Hours.

The proposal -If the system provisioning action forces the sensors to provide an average of one hour of total operation where it works Average (9 hours) instead of (10 hours).

Total bulb consumption in the building $= 100$ kw
Total fan consumption in the building $= 10.275$ kw
Total consumption of air condition in the building $= 75$ kw
Total loads consumption $= 100 + 10.275 + 75 = 185$ kw
Total annual consumption current $= 185 \times 10 \times 12 \times 26 = 577200$ kwh
New annual consumption $= 185 \times 9 \times 12 \times 26 = 519480$ kwh
Annual Savings = Total Annual Consumption Current − New Annual Consumption = $= 577200 - 519480 = 57720$ kwh

$$\% \text{ Savings } = \frac{\text{Amount of energy saving per year}}{\text{total New Energy Consumption per year}} \times 100 = \frac{(57720)}{(519480)} \times 100 = 11.1\%$$

% Savings in energy yields a reduction of CO2

$$= \frac{\text{Amount of energy saving per year}}{10000} \times 0.54 = \frac{(57720)}{(1000)} \times 0.54 = 31.1 \text{ tons}$$

Annual savings per pound $=$ Annual savings $\times$ Price(k. w. h) $= 57720 \times 0.90 = 51948$ LE

The payback period in years $=$ Total cost of nods

$$/\text{Energy Saving in LE} = \frac{(119500)}{(51948)} = 2.3$$

$\approx$ 2 Years and 3 Months

**Proposal II**

In this proposal, If the system by imposing a 20% energy saving

Total annual consumption current $= 185 \times 10 \times 12 \times 26 = 577200$ kW
New annual consumption $= 0.80 \times 185 \times 12 \times 26 = 461760$ kWh
Annual Savings = Total Annual Consumption Current − New Annual Consumption = $= 577200 - 461760 = 115440$ kWh

$$\% \text{ Savings } = \frac{\text{Amount of energy saving per year}}{\text{total New Energy Consumption per year}} \times 100 = \frac{(1155440)}{(461760)} \times 100 = 25\%$$

% Savings in energy yields a reduction of CO2

$$= \frac{\text{Amount of energy saving per year}}{10000} \times 0.54 = \frac{(115440)}{(1000)} \times 0.54 = 62.3 \text{ tons}$$

Annual savings per pound $=$ Annual savings $\times$ Price(k. w. h) $= 115440 \times 0.90 = 103896$ LE

The payback period in years $=$ Total cost of nods

$$/\text{Energy Saving in LE} = \frac{(119500)}{(103896)} = 1.2$$

$\approx$ 1 Years and 2 Months

## 6. CONCLUSIONS

In this paper, a case study was presented considering a governmental educational building in Cairo, Egypt. The study focused on saving energy via two methods:

1- Changing the lighting system by replacing the compact fluorescent lamps by longitudinal LED lamps. The proposed replacement saves about (20%) of the building energy consumption which results in the reduction of CO2 by about 95 tons per year. Not only that, the luminous intensity has very much improved. Practical implantation of the proposal was carried out on a lecture hole and an office. Experimental measurements before and after the installation validated the energy savings. Only by these two places, about (7500 LE) could be saved per year.
2- Using motion, heat, sound and light sensors Module which saves about (11.1%) of the building energy consumption which results in the reduction of CO2 by about (31.2%) tons per year. Experimental measurements before and after the installation validated the energy savings about (51948 LE) could be saved per year (purpose no (1)) and saves about (25%) of the building energy consumption which results in the reduction of CO2 by about (62.3%) tons per year. Experimental measurements before and after the installation validated the energy savings about (103896 LE) could be saved per year (purpose no (2)).

## Acknowledgments

The author would like to very much thank - Dr. Camilia Youssif and her team of the project: Energy Efficiency Improvement for Lighting and Household Appliances, Egypt. Their incredible support is very much appreciated.

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