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Comparative Study of Replacing Fluorescent Lamps by CFL and LED Lamps in Schools and Universities and Its Impact on the Environment and the Economy of the Country

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Authors' contributions

The contribution of the first author is that this is the first study that compares different type of technologies for lighting systems using software such as "Dialux" with a complete study about the impact of each technology on the economy of the country and on the environment. This study is applied in a public school but it can be generalized to all building sectors. The author demonstrates that the choice of a light source must not be chosen just to say that it is energy saving or energy efficient, but we have to take into consideration other factors and indicators similar to the presented ones in this paper in order to say if this technology is efficient or not.

Original Research Article

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ABSTRACT

In countries of the third world such as Lebanon (case of this paper), the organizations, schools, institutes, universities, etc. are searching to economize as possible the price of installation of electrical systems such as light sources, equipment and other electrical devices without taking into consideration the high impact of the electrical bill for such installations and without taking into consideration the environmental impact such as the emission of the CO2, toxic gases, mercury and the high fuel cost. This mentality is widely spread in Lebanon because the majority of owners and investors want to install the cheapest materials in order to reduce as possible the investment cost without taking into consideration the future impact of such installations even if they know that these installations have bad impact on the electrical bill and the environment. In this paper, the authors will discuss the installation of Fluorescent lamps particularly in schools and

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universities and how is it possible to replace these lamps by other lamps with high efficiency such as CFL and LED lamps. A comparative study is developed and the authors proposed solutions for such buildings and this study can be applied on a bigger scale for all building sectors in Lebanon. This study is the first study that compares different lighting technologies applied on a real building which is a school in Lebanon and it can be applied and generalized to all buildings in all sectors.

Aims: The aim of this study is to compare different technologies used for lighting system such as fluorescent, Compact Fluorescent Lamp (CFL), and LED installed in schools and universities in the third world especially in Lebanon and their impact on the economy of the country and the environment. This study emphasizes the important of the installation of LED technology in such buildings and its positive impact on the economy of the country and for many reasons developed in this paper.

Study Design: This study is developed using the software Dialux for lighting calculation and comparison between different technologies.

Place and Duration of Study: This study was made by the first author in a technical school (public school) in Hammana in Lebanon during the year 2014 using real measurements on site and using lighting software “Dialux” in order to compare different types of technologies.

Methodology: Real measurements were taken for the lighting load from private generator 60kVA and from power authority (EDL) for the existing lighting system (In the public school). The first author studied the distribution of lighting points for other technologies for the same lux level in each room. The calculation of the predicted load is done and a comparative table that shows different indicators for each technology and final the study is generalized for all schools and universities in Lebanon. The generalized study shows important results on the scale of the country in which the replacement of fluorescent lamps by LED lamps is enough to close 1.5 thermal power plants of the size 35MW in Tyre (south Lebanon) and to economize 2.16% of the total power consumption on the Lebanese scale.

Results: The replacement of fluorescent lamps (2x36W) by LED lamps as indicated in this paper will reduce the total power consumption on the Lebanese scale of 48.81 MW (2.16% from total power generated in Lebanon), the saved Energy is 52712.85 MWh/year, saved emission of CO2 from Fuel Oil is 35317.71 Ton of CO2/year, saved fuel consumption from private generators is 36990 liters/day (6,658,200 liters/year), saved cost of maintenance is 767,181$/year, Reduced Cost of electricity and maintenance is 8,955,141$/year, etc.

Conclusion: In this paper, the first author presents a comparative study between four different types of lamps (fluorescent 2x36W, CFL of type Philips, CFL of type Arcluce, LED of type ASTRA). This study emphasize the important of doing calculation using “DIALUX” software before selecting any type of lamps even if we consider this lamp is energy-saving. Moreover we have to take into consideration many indicators which are presented in this paper before buying any type of lamps. This study is a sample that helps all investors, owners, clients… to compare many types of lamps using indicators presented in this paper before buying them. We have to take also into consideration the impact on the environment such as the emission of the CO2, toxic gases, mercury…

In conclusion, the best choice of lamps in these days is the LED and of course a good quality and not of bad quality.

Keywords: Comparative study; fluorescent; CFL; LED; school; universities; Lebanon.

1. INTRODUCTION

In Lebanon, the majority of public schools, private schools, institutes, organizations, universities, etc. are using Fluorescent lamps in order to illuminate their buildings. These types of lamps are considered by the owners to be economic and less expansive compared to other type of lamps such as CFL and LED. But the problem that faces these institutions is the high cost of the electrical bill resulted from the installation of the Fluorescent lamps and the non negligible cost of maintenance for replacing tubes and ballasts each period depending on the quality of these tubes and ballasts. The others unseen effects are the pollution in the electrical network and the transformers. There is also an environmental impact which is the pollution such as CO2, toxic gases and especially the mercury (Hg) that is contained in these tubes which can't be recycled; we note that the mercury is very toxic. And moreover the other impact is that the production of electricity in Lebanon relies mainly on the fuel (more than 90% of power plants work using fuel).

In this paper, the author studied a case in Lebanon which is a public school and this study can be generalized to all building sectors such as public schools, private schools, institutes, organizations, universities, etc. in this paper a comparative study between the installed Fluorescent lamps and the proposed CFL and LED lamps is developed. In this paper, we can see clearly that the best decision to take in such buildings is to install LED lamps for many reasons which are discussed in this paper.

Remark: calculation of light sources, Lux level and distribution of lighting inside all rooms are done using the software “DIALUX 4.10”.

2. DESCRIPTION OF THE INITIATIVE

In this section, we are going to present and analyze the current situation of the chosen public school in which we are going to study its power consumption, fuel consumption, bill of electricity from own generator and from EDL (Power authority), CO2 emission, and mercury (Hg) impact on the environment.

To begin our study we have to admit the following information for this school:

- The school works 6 hours per day
- The number of teaching days is 180 days per year.
- The used currency in the paper is in US Dollar ($).
- The cost of 2 fluorescent tubes and ballast is approximately equal to 12$ in Lebanon.
- Cost of 1 kWh from Power Authority EDL (Electricite Du Liban): 0.0833$ USD it is fixed by the government
- The actual total load of the school is 31680W (average)
- The actual total load of school excluding the lighting load is 8033W (average)
- CO2 emission from Fuel Oil is: 670 gCO2/kWh (we consider that the generator is consuming fuel oil, the same for the electricity from EDL) [1]. We do not take into consideration the efficiency of the generator during lifetime.
- The Linear Fluorescent lamp (also called Fluorescent bulb) contains 10mg of mercury (Hg) [2-3], this is the available one in Lebanon. However some other modern Linear Fluorescent lamp contains 2-3mg mercury (This is not available till now in Lebanon).

- The CFL bulb contains 5mg of mercury [2-3], these are the available ones in Lebanon and they are studied in this paper. However some CFLs contain 1-2mg mercury.
- The LED lamp doesn't contain mercury [4].
- The school has a generator of 60kVA.
- The Fuel Consumption of the Generator 60kVA at full load is 16 Liters/Hour using fuel oil, 13 Liters/Hour for a load of 75%, 9 Liters/Hour for a load of 50%, and 6 Liters/Hour for a load of 25%.
- The cost of 1 liter of fuel oil is approximately equal to 0.9$ in Lebanon (for the private generator).

2.1 Presentation and Analyze of the Current Situation

The Table 1 represents the actual power consumption of the School using the Fluorescent light sources 2x36W (using electromagnetic ballast).

Table 1. represents the calculation of power consumption and the number of light sources in each room

Study about Existing light sources (Chinese Fluorescent 2x36W)						
Room	**Number of rooms**	**dimension of the room**	**power consumption per light source (in watt)**	**number of light sources per room**	**total power consumption (W)**	**Minimum Lux level required**
Classes	20	5m x 5m	107	6	12840	500
Room for drawing	2	10m x 5m	107	9	1926	500
Dining room	1	6m x 4m	107	3	321	300
Electrical Room	1	11m x 4.5m	107	6	642	300
Laboratory for computers	2	10m x 8m	107	15	3210	500
Elo Laboratory	1	5m x 5m	107	6	642	500
Corridor 1	1	14m x 2.7m	107	3	321	150
Corridor 2	1	11m x 1.6m	107	2	214	150
Offices	8	3.5m x 3.5m	107	3	2568	500
WC	3	5m x 5m	107	3	963	200
Total	**40**			**221**	**23647**	

The first column represents the activity in rooms, the second column represents the number of rooms in the school for each activity, the third column represents the dimension of each room in m2, the fourth column is the actual measurement of power taken for the lighting including the ballast for each light source, the fifth column represents the number of light sources in each room, the seventh column represents the total power consumption of all light sources for all rooms for each activity, the eighth column represents the required Lux level taken for each room, and in the end of the rows, the total summation is indicated.

2.1.1 Information about generator's consumption

- Actual measured Fuel Consumption of the Generator 60kVA at 66% of full load (31680W) is 11.56 Liters/Hour.
- Actual measured Fuel Consumption of the Generator 60kVA only for lighting (23647W) at 49.26% is 8.91 Liters/Hour.
- The average percentage of the lighting load in the school is 74.6% of the total load It is easily calculated from measurements taken on site.
- Quantity of fuel oil for the generator needed only for lighting per one day is

$$\mathrm{Q} = 8.91\left(\frac{\mathrm{liter}}{\mathrm{hour}}\right) \cdot 3\mathrm{hours} = 26.73\mathrm{liters}$$

- The generator works 3 hours per day, the total cost of Fuel Oil for generator needed only for lighting during a year is:

$$\mathrm{Cost}_{\mathrm{Fuel\ Oil}} = 26.73\left(\frac{\mathrm{liters}}{\mathrm{day}}\right) \cdot 180\left(\frac{\mathrm{day}}{\mathrm{year}}\right) \cdot 0.9\left(\frac{\$}{\mathrm{liter}}\right) = 4330.26\left(\frac{\$}{\mathrm{year}}\right)$$

2.1.2 Information about consumption from power authority (EDL)

In the Lebanese case, and especially in the region when the school is located, the electricity from power authority (EDL) is available only 3 hours from 8:00Am till 11:00Am every day; therefore the school is supplied only 3 hours per day from the Power Authority and the other 3 hours from the private Generator.

Total cost of the Electrical Bill only for lighting from the Power Authority EDL during a year is:

$$\mathrm{Cost}_{\mathrm{EDL}} = 23.647\mathrm{kW} \cdot 3\left(\frac{\mathrm{hours}}{\mathrm{day}}\right) \cdot 180\left(\frac{\mathrm{day}}{\mathrm{year}}\right) \cdot 0.0833\left(\frac{\$}{\mathrm{kWh}}\right) = 1063.69\left(\frac{\$}{\mathrm{year}}\right)$$

2.1.3 Total cost of electrical bill only for lighting load during a year

Total cost of electrical bill only for lighting load during a year is:

$$\mathrm{Total\ Cost}_{\mathrm{Lighting}} = \mathrm{Cost}_{\mathrm{Fuel\ Oil}} + \mathrm{Cost}_{\mathrm{EDL}} = 4330.26\left(\frac{\$}{\mathrm{year}}\right) + 1063.69\left(\frac{\$}{\mathrm{year}}\right) = 5393.95\left(\frac{\$}{\mathrm{year}}\right)$$

2.1.4 Lifetime of Fluorescent lamp and its impact on the cost

The lifetime duration of such lamp is approximately 9000 hours (it depends on the manufacturer and on the quality, (for the chosen one in this paper is from Philips catalog 2012).

In our case, the school works 6 hours per day, the average life time duration of the lamps is

$$\mathrm{number\ of\ years} = \frac{9000\mathrm{hours}}{6(\mathrm{hours/day}) \cdot 180(\mathrm{day/year})} = 8.33\mathrm{years}$$

Maintenance cost of changing bulbs and ballasts per year:

$$\text{maintenance} = 221(\text{light source}) \cdot \frac{12(\$)}{8.33\text{years}} = 318.367\left(\frac{\$}{\text{year}}\right)$$

2.1.5 Total cost of electrical bill and maintenance per year

The total cost of electrical bill and maintenance per year is:

$$\text{total cost} = \text{Total Cost}_{\text{Lighting}} + \text{maintenance} = 5393.95\left(\frac{\$}{\text{year}}\right) + 318.367\left(\frac{\$}{\text{year}}\right) = 5712.317\left(\frac{\$}{\text{year}}\right)$$

2.1.6 Average emission of mercury per year

As we have seen in the sub-section 2.1.4, the lifetime of fluorescent bulb is 9000hours (8.33years of work), so we have to change all bulbs every 8.33 years and the average number of changed bulbs per year is:

$$\text{average number of changed bulbs per year} = 221(\text{light source}) \cdot \frac{2(\text{bulbs})}{8.33\text{years}} = 53.06\text{bulbs}$$

The average emission of mercury in mg per year is:

$$\text{emission of mercury per year} = 53.06(\text{bulbs}) \cdot 10(\text{mg of Hg}) = 530.6\text{mg of Hg per year}$$

2.1.7 Analyze of the current situation

It is clear that the fluorescent lamps have negative impact on the environment by emitting mercury which is very toxic for the health and for the soil, and on the electrical bill because of the high power consumption. There is also high fuel oil consumption which produces CO2 and sulfur oxide in large quantities only to supply the lighting load in the school.

Another disadvantage is that the electricity is not stable in Lebanon, the voltage is not stable and the frequently switching On/Off of the fluorescent lamps will reduce its lifetime. So the cost of changing bulbs and ballasts will increase.

2.2 Strong and Weak Elements of the Initiative

Strong elements:

- The cost of fluorescent bulbs and ballasts are relatively low compared to CFL bulbs and LED lamps.
- The temperature of the bulb is around 35C (less than the incandescent lamp).

Weak elements:

- Fluorescent bulbs convert only 22% of the input power to visible light.
- The ballast loss can be about 25% of the lamp power with magnetic ballasts, and around 10% with electronic ballasts.
- They contain mercury Hg which is toxic for the health and for the soil.

- There is no treatment of fluorescent bulbs in Lebanon and all these bulbs are thrown in the soil or in the sea.
- The fluorescent bulbs are sensitive to Temperature and humidity in which the efficiency varies.
- These bulbs take time to be turned on (few seconds).
- The glass can be broken easily.
- High power consumption, 107W per light source (2x36W + ballast) compared to CFL and LED.
- The fluorescent bulb has cylindrical form which means loss of direct light in the upper side.
- Lifetime is very small compared to CFL and LED.
- Fluorescent and CFL bulbs emit a small amount of ultraviolet light which can have negative effect on the human being and cause health problems [5].
- Etc.

2.3 Identification of Barriers for Implementation

In the Lebanese case, the public schools and universities don't have the authority to do any modification or improvement without the agreement of the government. The replacement of fluorescent lamps by CFL or LED lamps must take the agreement of the government and need investment from the government.

For the private schools and universities it is much easier to take such decision especially when this decision will lead to an improvement of the existing system and to reduce the power consumption and the electricity bill. And moreover, the most important thing that encourages the private schools and universities to do such investment is that the return on investment is much lower than the lifetime of the proposed installation.

For the public case, this study will be presented to the general managers of the schools and universities in order to give them a brief review about the impact of replacing the existing fluorescent lamps by CFL or by LED lamps. This study will cover the impact on the electricity bill and the environment. The second step is to represent this study to the government in order to take a serious decision to help all public schools, universities and other organizations to invest in such project which has economical and environmental impact on the country.

In Lebanon, according to the website [6], we have 1364 private schools, 1146 primary public schools, 250 secondary public schools, 97 public vocational (technical) schools excluding Beirut (the capital), 11 private vocational schools, 42 private universities, 5 branches of the Lebanese university (85 buildings), and other institutes which have the same type of installation (fluorescent lamps) but with different averages of power consumption. In this paper, in order to not complicate the study, we consider that all these institutes, schools and universities have the same power consumption just to generalize our study for the whole country and to see the impact on the environment and on the economy of the country.

3. STUDY OF REPLACING THE EXISTING FLUORESCENT LIGHT BY TL5 CIRCULAR LAMP OF TYPE (PHILIPS, TYPE ROTARIS TCS740, 60W)

In this section we are going to study the possibility of replacing the existing fluorescent 2x36W lamps by TL5 Circular lamps of type (Philips, type Rotaris TCS740, 60W).

Table 2. Represents the calculation of power consumption and the number of light sources in each room

Study about replacing existing light source (fluorescent) by TL5 Circular lamp light source (Philips, type Rotaris TCS740, 60W)						
Room	**Number of rooms**	**Dimension of the room**	**Power consumption per light source (in watt)**	**Number of light sources per room**	**Total power consumption (W)**	**Minimum Lux level required**
Classes	20	5m x 5m	65	8	10400	500
Room for drawing	2	10m x 5m	65	15	1950	500
Dining room	1	6m x 4m	65	6	390	300
Electrical Room	1	11m x 4.5m	65	9	585	300
Laboratory for computers	2	10m x 8m	65	20	2600	500
Elo Laboratory	1	5m x 5m	65	8	520	500
Corridor 1	1	14m x 2.7m	65	4	260	150
Corridor 2	1	11m x 1.6m	65	3	195	150
Offices	8	3.5m x 3.5m	65	4	2080	500
WC	3	5m x 5m	65	3	585	200
Total	**40**			**301**	**19565**	

In the Table 2, the total number of lighting sources is 301 using Philips-Rotaris TCS740, 60W, in fact its power consumption is 65W per lamp and the total power consumption is

$$\mathrm{P} = 19565\mathrm{W}$$

- The price of such light source is approximately 52$ in Lebanon
- The total price of all light sources is

$$\text{Total price} = 301\text{lamps} \cdot 52\$ = 15652\$$$

- The installation of one light source is 9$ in Lebanon, the total cost of installation is

$$\text{Total cost of installation} = 301\text{lamps} \cdot 9\$ = 2709\$$$

- The total cost of lamps including the installation (Investment) is

$$\text{Total cost} = 15652\$ + 2709\$ = 18361\$$$

3.1 Lifetime of TL5 Circular Lamp and Its Impact on the Cost

- The lifetime duration of such lamp is approximately 19000 hours.

In our case, the school works 6 hours per day, the average lifetime duration of the lamps is

$$\text{number of years} = \frac{19000\text{hours}}{6(\text{hours/day}) \cdot 180(\text{day/year})} = 17.59\text{years}$$

- Cost of the TL5 Circular lamp for the type Philips-Rotaris TCS740, 60W in Lebanon:

$$\text{Cost of the CFL bulb} = 14\$$$

- Maintenance cost of changing bulbs and ballasts per year:

$$301(\text{light source}) \cdot \frac{14(\$)}{17.59\text{years}} = 239.568\left(\frac{\$}{\text{year}}\right)$$

3.2 Reducing the Generator's Consumption and Cost

- The power consumption of lighting is 21125W, and its percentage is

$$\frac{19565\text{W}/0.8}{60\text{kVA}} 100\% = 40.76\%$$

Its consumption in fuel oil is 7.89 Liters/Hour.

- Quantity of fuel oil for the generator needed only for lighting per on day is

$$\text{Q} = 7.89\left(\frac{\text{liter}}{\text{hour}}\right) \cdot 3\text{hours} = 23.67\text{liters}$$

- The generator works 3 hours per day, the total cost of Fuel Oil for generator needed only for lighting during a year is:

$$\text{Cost}_{\text{Fuel Oil}} = 23.67\left(\frac{\text{liters}}{\text{day}}\right) \cdot 180\left(\frac{\text{day}}{\text{year}}\right) \cdot 0.9\left(\frac{\$}{\text{liter}}\right) = 3834.54\left(\frac{\$}{\text{year}}\right)$$

3.3 Reducing the Consumption from Power Authority (EDL)

- Total cost of the Electricity Bill only for lighting from the Power Authority EDL during a year is:

$$\text{Cost}_{\text{EDL}} = 19.565\text{kW} \cdot 3\left(\frac{\text{hours}}{\text{day}}\right) \cdot 180\left(\frac{\text{day}}{\text{year}}\right) \cdot 0.0833\left(\frac{\$}{\text{kWh}}\right) = 880.072\left(\frac{\$}{\text{year}}\right)$$

3.4 Total Cost of Electrical Bill Only for Lighting Load during a Year

Total cost of electrical bill only for lighting load during a year is:

$$\text{Total Cost}_{\text{Lighting}} = \text{Cost}_{\text{Fuel Oil}} + \text{Cost}_{\text{EDL}} = 3834.54\left(\frac{\$}{\text{year}}\right) + 880.072\left(\frac{\$}{\text{year}}\right)$$
$$= 4714.612\left(\frac{\$}{\text{year}}\right)$$

3.5 Cost Reduction of Fuel oil per year

- Reduced cost per year compared to the existing lighting is:

$$5393.95\left(\frac{\$}{\text{year}}\right) - 4714.612\left(\frac{\$}{\text{year}}\right) = 679.338\left(\frac{\$}{\text{year}}\right)$$

3.6 Cost Reduction of Maintenance per Year

- The reduced cost of maintenance per year is

$$318.367\left(\frac{\$}{\text{year}}\right) - 239.568\left(\frac{\$}{\text{year}}\right) = 78.8\left(\frac{\$}{\text{year}}\right)$$

3.7 Total Reduced Cost Including Fuel Oil and Maintenance

The total reduced cost including fuel oil cost and maintenance cost is:

$$\left(5393.95\left(\frac{\$}{\text{year}}\right) + 318.367\left(\frac{\$}{\text{year}}\right)\right) - \left(4714.612\left(\frac{\$}{\text{year}}\right) + 239.568\left(\frac{\$}{\text{year}}\right)\right) = 759.137\left(\frac{\$}{\text{year}}\right)$$

3.8 Average Emission of Mercury per Year

- As we have seen in the sub-section 3.1, the lifetime of TL5 Circular lamp is 19000hours (17.59 years of work), so we have to change all bulbs every 17.59 years and the average number of changed bulbs per year is:

$$\text{average number of changed bulbs per year} = 301(\text{light source}) \cdot \frac{1(\text{bulb})}{17.59\text{years}} = 17.11\text{bulbs}$$

- The average emission of mercury in mg per year is:

$$\text{emission of mercury per year} = 17.11(\text{bulbs}) \cdot 5(\text{mg of Hg}) = 85.56\text{mg of Hg per year}$$

3.9 Calculation of Indicators

- Calculate the Return On Investment:

$$\text{ROI} = \frac{\text{Investment}}{\text{total reduced cost per year}} = \frac{18361\$}{759.137\left(\frac{\$}{\text{year}}\right)} = 24.186\text{years}$$

More indicators are presented in the Table 5 in the section 6.

4. REPLACING THE EXISTING FLUORESCENT LIGHT BY CFL OF TYPE (ARCLUCE, TYPE 4993 OPTICAL-PL SOFT, 55W)

In this section we are going to study the possibility of replacing the existing fluorescent 2x36W lamps by CFL lamps of type (Arcluce, type 4993 Optical-PL soft, 55W).

Table 3. Represents the calculation of power consumption and the number of light sources in each room

Study about replacing existing light source (fluorescent) by Compact Fluorescent light source (Arcluce, type 4939 Optical-PL soft, 55W)						
Room	**Number of rooms**	**Dimension of the room**	**Power consumption per light source (in watt)**	**Number of light sources per room**	**Total power consumption (W)**	**Minimum Lux level required**
Classes	20	5m x 5m	55	6	6600	500
Room for drawing	2	10m x 5m	55	12	1320	500
Dining room	1	6m x 4m	55	4	220	300
Electrical Room	1	11m x 4.5m	55	8	440	300
Laboratory for computers	2	10m x 8m	55	16	1760	500
Elo Laboratory	1	5m x 5m	55	6	330	500
Corridor 1	1	14m x 2.7m	55	3	165	150
Corridor 2	1	11m x 1.6m	55	2	110	150
Offices	8	3.5m x 3.5m	55	4	1760	500
WC	3	5m x 5m	55	3	495	200
Total	**40**			**240**	**13200**	

In the Table 3, the total number of lighting sources is 240 using Arcluce, type 4993 Optical-PL soft, 55W, the total power consumption is

$$\mathrm{P} = 13200\mathrm{W}$$

- The price of such light source is approximately 65$ in Lebanon
- The total price of all light sources is

$$\text{Total price} = 240\text{lamps} \cdot 65\$ = 15600\$$$

- The installation of one light source is 9$ in Lebanon, the total cost of installation is
-

$$\text{Total cost of installation} = 240\text{lamps} \cdot 9\$ = 2160\$$$

- The total cost of lamps including the installation (Investment) is

$$\text{Total cost} = 15600\$ + 2160\$ = 17760\$$$

4.1 Lifetime of CFL Lamp and its Impact on the Cost

- The lifetime duration of such lamp is approximately 12000 hours.
  In our case, the school works 6 hours per day, the average lifetime duration of the lamps is

$$\text{number of years} = \frac{12000\text{hours}}{6(\text{hours/day}) \cdot 180(\text{day/year})} = 11.11\text{years}$$

- Cost of the CFL bulb for the type Arcluce, type 4939 Optical-PL soft, 55W in Lebanon:

$$\text{Cost of the CFL bulb} = 15\$$$

- Maintenance cost of changing bulbs and ballasts per year:

$$240(\text{light source}) \cdot \frac{15(\$)}{11.11\text{years}} = 324\left(\frac{\$}{\text{year}}\right)$$

4.2 Reducing the Generator's Consumption and Cost

- The power consumption of lighting is 13200W, and its percentage is

$$\frac{13200\text{W}/0.8}{60\text{kVA}} 100\% = 27.5\%$$

Its consumption in fuel oil is 6.3 Liters/Hour.

- Quantity of fuel oil for the generator needed only for lighting per on day is

$$\text{Q} = 6.3\left(\frac{\text{liter}}{\text{hour}}\right) \cdot 3\text{hours} = 18.9\text{liters}$$

- The generator works 3 hours per day, the total cost of Fuel Oil for generator needed only for lighting during a year is:

$$\text{Cost}_{\text{Fuel Oil}} = 18.9\left(\frac{\text{liters}}{\text{day}}\right) \cdot 180\left(\frac{\text{day}}{\text{year}}\right) \cdot 0.9\left(\frac{\$}{\text{liter}}\right) = 3061.8\left(\frac{\$}{\text{year}}\right)$$

4.3 Reducing the Consumption from Power Authority (EDL)

Total cost of the Electrical Bill only for lighting from the Power Authority EDL during a year is:

$$\text{Cost}_{\text{EDL}} = 13.2\text{kW} \cdot 3\left(\frac{\text{hours}}{\text{day}}\right) \cdot 180\left(\frac{\text{day}}{\text{year}}\right) \cdot 0.0833\left(\frac{\$}{\text{kWh}}\right) = 593.762\left(\frac{\$}{\text{year}}\right)$$

4.4 Total Cost of Electrical Bill Only for Lighting Load during a Year

Total cost of electrical bill only for lighting load during a year is:

$$\text{Total Cost}_{\text{Lighting}} = \text{Cost}_{\text{Fuel Oil}} + \text{Cost}_{\text{EDL}} = 3061.8\left(\frac{\$}{\text{year}}\right) + 593.762\left(\frac{\$}{\text{year}}\right) = 3655.562\left(\frac{\$}{\text{year}}\right)$$

4.5 Cost Reduction of Fuel Oil per Year

- Reduced cost per year compared to the existing lighting is:

$$5393.95\left(\frac{\$}{\text{year}}\right)-3655.562\left(\frac{\$}{\text{year}}\right)=1738.388\left(\frac{\$}{\text{year}}\right)$$

4.6 Cost Reduction of Maintenance per Year

- The reduced cost of maintenance per year is
-

$$318.367\left(\frac{\$}{\text{year}}\right)-324\left(\frac{\$}{\text{year}}\right)=-5.633\left(\frac{\$}{\text{year}}\right)$$

Which means the maintenance cost of this type of CFL is higher than the Fluorescent installed

4.7 Total Reduced Cost Including Fuel Oil and Maintenance

The total reduced cost including fuel oil cost and maintenance cost is:

$$\left(5393.95\left(\frac{\$}{\text{year}}\right)+318.367\left(\frac{\$}{\text{year}}\right)\right)-\left(3655.562\left(\frac{\$}{\text{year}}\right)+324\left(\frac{\$}{\text{year}}\right)\right)=1732.755\left(\frac{\$}{\text{year}}\right)$$

4.8 Average Emission of Mercury per Year

- As we have seen in the sub-section 4.1, the lifetime of CFL bulb is 12000hours (11.11 years of work), so we have to change all bulbs every 11.11 years and the average number of changed bulbs per year is:

$$\text{average number of changed bulbs per year}=240(\text{light source})\cdot\frac{1(\text{bulb})}{11.11\text{years}}=21.6\text{bulbs}$$

- The average emission of mercury in mg per year is:

$$\text{emission of mercury per year}=21.6(\text{bulbs})\cdot 5(\text{mg of Hg})=108\text{mg of Hg per year}$$

4.9 Calculation of Indicators

- Calculate the Return On Investment:

$$\text{ROI}=\frac{\text{Investment}}{\text{Reduced cost per year}}=\frac{17760\$}{1732.755\left(\frac{\$}{\text{year}}\right)}=10.25\text{years}$$

More indicators are presented in the Table 5 in the section 6.

5. REPLACING THE EXISTING FLUORESCENT LIGHT BY LED LIGHT OF TYPE (ASTRA, TYPE ASM 30W Cool XL)

In this section we are going to study the possibility of replacing the existing fluorescent 2x36W lamps by LED lamps of type (ASTRA, type ASM 30W Cool XL) with Cool white Color 5000-6000K. This LED lamp is CE marked, produced according to European norm EN 60598-2-2:1996/A1:1997.

Table 4. Represents the calculation of power consumption and the number of light sources in each room

Study about replacing existing light source (fluorescent) by LED light source (ASTRA, type ASM 30W Cool XL)						
Room	**Number of rooms**	**Dimension of the room**	**Power consumption per light source (in watt)**	**Number of light sources per room**	**Total power consumption (W)**	**Minimum Lux level required**
Classes	20	5m x 5m	31.8	6	3816	500
Room for drawing	2	10m x 5m	31.8	12	763.2	500
Dining room	1	6m x 4m	31.8	3	95.4	300
Electrical Room	1	11m x 4.5m	31.8	8	254.4	300
Laboratory for computers	2	10m x 8m	31.8	18	1144.8	500
Elo Laboratory	1	5m x 5m	31.8	6	190.8	500
Corridor 1	1	14m x 2.7m	31.8	3	95.4	150
Corridor 2	1	11m x 1.6m	31.8	2	63.6	150
Offices	8	3.5m x 3.5m	31.8	3	763.2	500
WC	3	5m x 5m	31.8	2	190.8	200
Total	**40**			**232**	**7377.6**	

In the Table 4, the total number of lighting sources is 232 using ASTRA, type ASM 30W Cool XL, the total power consumption is

$$\mathrm{P} = 7377.6\mathrm{W}$$

- The price of such light source is approximately 164$ in Lebanon
- The total price of all light sources is

$$\text{Total price} = 232\text{lamps} \cdot 164\$ = 38048\$$$

- The installation of one light source is 9$ in Lebanon, the total cost of installation is

$$\text{Total cost of installation} = 232\text{lamps} \cdot 9\$ = 2088\$$$

- The total cost of lamps including the installation (Investment) is

$$\text{Total cost} = 38048\$ + 2088\$ = 40136\$$$

We have to mention that the cost of LEDs is going down rapidly each year. This would have a major effect on the total installation cost. It is predicted that the price of the LED lamps will cut in half by 2020 [8], therefore the total cost will be

$$\text{Predicted Total cost by } 2020 = \frac{40136\$}{2} \approx 20000\$$$

For the moment, we suppose that we are going to apply this study in this year.

5.1 Lifetime of LED Lamp and its Impact on the Cost

- The life time duration of such lamp is 100000 hours

In our case, the school works 6 hours per day, the average life time duration of the lamps is

$$\text{number of years} = \frac{100000\text{hours}}{6\left(\frac{\text{hours}}{\text{day}}\right) \cdot 180\left(\frac{\text{day}}{\text{year}}\right)} = 92.59\text{years}$$

- Cost of the LED bulb for the type ASTRA, type ASM 30W Cool XL in Lebanon:

$$\text{Cost of the ASTRA LED} = 25\$$$

- Maintenance cost of changing bulbs per year:

$$232(\text{light source}) \cdot \frac{25(\$)}{92.59\text{years}} = 62.64\left(\frac{\$}{\text{year}}\right)$$

Practically we can consider it negligible because even after 100000 hours the LED still work but with low efficiency. But for our study we will take it equal to $62.64\left(\frac{\$}{\text{year}}\right)$

We have to notice that the manufacturer ASTRA claims that the lifetime of their LED light sources is 100,000 hours. Moreover they have been working for more than 10 years in our country and they didn't face any problem in any installation during these years. This will provide a reasonable assumption for the lifetime of their LEDs. Someone will ask if the existing building we stay for 92.59 years or it will be remodeled before this duration, maybe this question can be applied in developed countries but it doesn't apply for developing countries such as Lebanon in which the installation will be the same as long as the building exists and especially for the public sector such as schools, universities and other institutes. The only modification in such buildings can be the change of light sources, using solar panels, using photovoltaic panels or other minor changes, but there is no other changes are remarked in such buildings even in private sectors.

5.2 Reducing the Generator's Consumption and Cost

- The power consumption of lighting is 7377.6W, and its percentage is

$$\frac{7377.6\text{W}/0.8}{60\text{kVA}} 100\% = 15.37\%$$

Its consumption in fuel oil is 4.8 Liters/Hour.

- Quantity of fuel oil for the generator needed only for lighting per on day is

$$Q = 4.8\left(\frac{\text{liter}}{\text{hour}}\right) \cdot 3\text{hours} = 14.4\text{liters}$$

- The generator works 3 hours per day, the total cost of Fuel Oil for generator needed only for lighting during a year is:

$$\text{Cost}_{\text{Fuel Oil}} = 14.4\left(\frac{\text{liters}}{\text{day}}\right) \cdot 180\left(\frac{\text{day}}{\text{year}}\right) \cdot 0.9\left(\frac{\$}{\text{liter}}\right) = 2332.8\left(\frac{\$}{\text{year}}\right)$$

5.3 Reducing the Consumption from Power Authority (EDL)

- Total cost of the Electrical Bill only for lighting from the Power Authority EDL during a year is:

$$\text{Cost}_{\text{EDL}} = 7.377\text{kW} \cdot 3\left(\frac{\text{hours}}{\text{day}}\right) \cdot 180\left(\frac{\text{day}}{\text{year}}\right) \cdot 0.0833\left(\frac{\$}{\text{kWh}}\right) = 331.83\left(\frac{\$}{\text{year}}\right)$$

5.4 Total Cost of Electrical Bill Only for Lighting Load during a Year

Total cost of electrical bill only for lighting load during a year is:

$$\text{Total Cost}_{\text{Lighting}} = \text{Cost}_{\text{Fuel Oil}} + \text{Cost}_{\text{EDL}} = 2332.8\left(\frac{\$}{\text{year}}\right) + 331.83\left(\frac{\$}{\text{year}}\right) = 2664.63\left(\frac{\$}{\text{year}}\right)$$

5.5 Cost Reduction of Fuel Oil per Year

- Reduced cost per year compared to the existing lighting is:

$$5393.95\left(\frac{\$}{\text{year}}\right) - 2664.63\left(\frac{\$}{\text{year}}\right) = 2729.32\left(\frac{\$}{\text{year}}\right)$$

5.6 Cost Reduction of Maintenance per Year

- The reduced cost of maintenance per year is

$$318.367\left(\frac{\$}{\text{year}}\right) - 62.64\left(\frac{\$}{\text{year}}\right) = 255.727\left(\frac{\$}{\text{year}}\right)$$

5.7 Total Reduced Cost Including Fuel Oil and Maintenance

The total reduced cost including fuel oil cost and maintenance cost is:

$$\left(5393.95\left(\frac{\$}{\text{year}}\right) + 318.367\left(\frac{\$}{\text{year}}\right)\right) - \left(2664.63\left(\frac{\$}{\text{year}}\right) + 62.64\left(\frac{\$}{\text{year}}\right)\right) = 2985.047\left(\frac{\$}{\text{year}}\right)$$

5.8 Calculation of Indicators

- Calculate the Return On Investment:

$$\mathrm{ROI} = \frac{\mathrm{Investment}}{\mathrm{Reduced\ cost\ per\ year}} = \frac{40136\$}{2985.047\left(\frac{\$}{\mathrm{year}}\right)} = 13.44\mathrm{years}$$

More indicators are presented in the Table 5 in the section 6.

By 2020, if we apply this study when the price of LED lamps is cut in half, therefore the return on investment will be:

$$\mathrm{ROI\ by\ 2020} = \frac{\mathrm{Investment}}{\mathrm{Reduced\ cost\ per\ year}} = \frac{20000\$}{2985.047\left(\frac{\$}{\mathrm{year}}\right)} = 6.7\mathrm{years}$$

6. RESULTS AND PROPOSED INDICATORS

In this section, a complete table shows the comparison between the 4 types of lamps and its impact on a single school. The indicators are shown in the first column.

Table 5. Comparative table between the 4 types of light sources

Description and indicators	**Existing Lighting (Type 2x36W)**	**TL5 Circular lamp of type (Philips, type Rotaris TCS740, 60W)**	**CFL of type (Arcluce, type 4993 Optical-PL soft, 55W)**	**LED light of type (ASTRA, type ASM 30W Cool XL)**
Power consumption in kW	23.647 kW	19.565 kW	13.2kW	7.3776kW
Energy consumption per year in kWh (P x 6h x 180day)	25538.76 kWh	21130.2 kWh	14256 kWh	7967.81 kWh
CO2 emission from Fuel Oil only for lighting during a year (0.67kgCO2/kWh)	17111 kg of CO2/year	14157.23kg of CO2/year	9551.52 kg of CO2/year	5338.43 kg of CO2/year
Reduction of CO2 in % Reduction in energy in % Reduction in Power in %	0%	17.26%	44.18%	68.8%
Fuel Oil Consumption in liters per day only for lighting and from private generator in the school	26.73 liters/day (4811.4liters/year)	23.67 liters/day (4260.6liters/ year)	18.9 liters/day (3402liters/year)	14.4 liters/day (2592liters/year)
Number of lighting points	221	301	240	232
Cost of Electrical Bill during one year	5393.95 $/year	4714.612 $/year	3655.562 $/year	2664.63 $/year
Cost of Maintenance per year (changing bulbs)	318.367$/year	239.568 $/year	324 $/year	62.64 $/year

Table 5 Continued….

Reduction Cost of electricity and maintenance in $	x	759.137 $/year	1732.755 $/year	2985.047 $/year
Reduction Cost of electricity and maintenance per year in %	x	13.27 %	30.33%	52.256%
Emission of Mercury in mg per year	530.6 mg/year	85.56 mg/year	108 mg/year	x
Reduction of mercury in %	0%	83.87%	79.64%	100%
Investment	x	18361 $	17760 $	40136 $
ROI (Return On Investment) including the cost of maintenance	x	24.186 years	10.25 years	13.44 years
$\boldsymbol{VAN = G\left(\frac{1-\frac{1}{(1+i)^n}}{i}\right) - INV}$ For i=5%, n=100years, G=gain per year, Inv=investment.	x	-3293.72$ we are losing money for a duration of 100years	16631.56$ we are gaining money for a duration of 100years	19110.94$ we are gaining money for a duration of 100years
Sensitivity to low temperatures and humidity on the Lamp	Yes	Yes	Yes	No
Effect of the switching on the lifetime of the lamp	Yes	Yes	Yes	No
Sensitivity to temperature, humidity and switching on the ballast and electronic driver	Yes	Yes	Yes	Yes

7. DISCUSSION AND METHOD OF EVALUATION

7.1 Choice between CFL (Compact Fluorescent Lamp) an TL5 Circular Lamp

1. If we compare the two types from two different manufacturers such as “Philips” and “Arculce” in this paper for the same Lux level, we can see clearly that the power and energy consumption of the CFL of type (Arcluce, type 4993 Optical-PL soft, 55W) is much lower than the TL5 Circular lamp of type (Philips, type Rotaris TCS740, 60W), which means that if we want to reduce the power consumption of our lighting system, then we have just not to think to replace a Fluorescent lamp by any type of CFL or TL5 Circular lamp, but we have to demonstrate by calculation using software such as “DIALUX” what is the best choice of light sources, and we have to compare them taking into consideration many indicators and factors such as same Lux level, the lifetime of lamps, the cost of investment, the cost of maintenance, the return of investment, etc.
2. For the same Lux level for the whole school we can see clearly that the number of light sources using “Arcluce” is much lower than the same light sources of type “Philips” which means a reduction in the cost of installation and maintenance.

3. We have to take into consideration the environment and the emission of the CO2, therefore for the same installation, we have to reduce as possible the consumption of fuel therefore reduce the emission of the CO2 and other toxic gases. This means we have to apply the Energy Efficiency requirements to our buildings.
4. CFL lamps contain mercury which is harmful, humans can develop serious health problems, it Cannot dispose in domestic waste, Cannot be recycled, If mercury (Hg) gets into the ecosystem it can evolve into a more harmful variant that can cause serious contamination to our food and water supplies [4].
5. The VAN value of TL5 Circular lamp of type (Philips, type Rotaris TCS740, 60W) is negative which means that replacing fluorescent lamps by these lamps is not efficient at all and it cause losses for a long duration when the interest is taken equal to 5%.

7.2 Choice between CFL, TL5 Circular Lamp and LED

1. If we compare CFL, TL5 Circular lamp light sources and LED light sources in the Table 5, we can see clearly that the LED technology is much more important than the CFL technology in all aspects. Firstly the power consumption is reduced to the half, the fuel consumption is reduced to the half, the CO2 emission is reduced, the mercury is eliminated, the Return On Investment is reduced, etc… so between LED, TL5 Circular lamp and CFL our choice will be of course LED even if its cost of investment is much higher.
2. The lifetime of LED light sources is approximately equal to 100,000 hours compared to 19,000 hours for CFL. Moreover the efficiency during the lifetime of the LED doesn't vary significantly (decrease only 2% after 50000 hours as per the catalog of ASTRA) but for the CFL it will be reduced drastically.
3. The temperature of LED lamps is much lower compared to the CFL lamps. No need for air conditioning (reduced power consumption).
4. The LED lamps are mercury free.
5. Low harmonic distortion compared to CFL and TL5 Circular lamp, therefore low impact on the transformers.
6. The choice of LED lamps will be based on the calculation using "DIALUX", we don't choose low quality LED lamps produced in developing countries but our choice must be very good quality of LED with very good Lumen.
7. Etc.

Thus, if we evaluate according to the Table 5, our choice will be the LED technology even if the cost of investment is much higher.

7.3 Generalization of This Study for All Lebanese Schools and Universities

The total number of schools and universities in Lebanon is approximately equal to 3000. In order to simplify our study, we consider that all schools and universities have the same power consumption similar to the presented school in this paper.

The general study of all schools and universities is presented in the following Table 6.

Table 6. Comparative table between 4 types of lighting sources for educational sector in Lebanon (only for schools and universities)

Description and indicators	Existing Lighting (Type 2x36W)	CFL of type (Philips, type Rotaris TCS740, 60W)	CFL of type (Arcluce, type 4993 Optical-PL soft, 55W)	LED light of type (ASTRA, type ASM 30W Cool XL)
Power consumption in MW	70.941 MW	58.695 MW	39.6 MW	22.1328 MW
Energy consumption per year in MWh (P x 6h x 180day)	76616.28 MWh	63390.6 MWh	42768 MWh	23903.43 MWh
CO2 emission from Fuel Oil only for lighting during a year (0.67kgCO2/kWh)	51333 Ton of CO2/year	42471.69 Ton of CO2/year	28654.56 Ton of CO2/year	16015.29 Ton of CO2/year
Reduction of CO2 in % Reduction in energy in % Reduction in Power in %	0%	17.26%	44.18%	68.8%
Fuel Oil Consumption in liters per day only for lighting and from generator in the school	80190 liters/day	71010 liters/day	56700 liters/day	43200 liters/day
Cost of Electrical Bill during one year	16,181,850 $/year	14,143,836 $/year	10,966,686 $/year	7,993,890 $/year
Cost of Maintenance per year (changing bulbs)	955,101 $/year	718,704 $/year	972,000 $/year	187,920 $/year
Reduction Cost of electricity and maintenance in $	x	2,277,411 $/year	5,198,265$/year	8,955,141$/year
Reduction Cost of electricity and maintenance per year in %	x	13.27 %	30.33%	52.256%
Emission of Mercury in kg per year	1.59 kg/year	0.25668 kg/year	0.324 kg/year	x
Reduction of mercury in %	0%	83.87%	79.64%	100%
Investment	x	55,083,000 $	53,280,000 $	120,408,000 $
ROI (Return On Investment) including the cost of maintenance	x	24.186 years	10.25years	13.44 years

Table 6 Continued…..

$VAN = G\left(\frac{1-\frac{1}{(1+i)^n}}{i}\right) - INV$ For i=5%, n=100years, G=gain per year, Inv=investment.	x	-9,881,151$ we are losing money for a duration of 100years	49,894,680$ we are gaining money for a duration of 100years	57,332,834.4$ we are gaining money for a duration of 100years

7.4 Cost, Benefits and Advantages of Replacing the Existing Fluorescent Lamps (2x36W) by LED Lamps

The cost of such project on the Lebanese scale is: 120,408,000 $

The benefits and advantages of replacing the existing fluorescent lamps (2x36W) by LED lamps of type (ASTRA, type ASM 30W Cool XL) are as following:

- Saved power: 48.81 MW (saving one and half thermal power plants such as TYR 1 of 35MW in Tyre) (2.16% from total power generated in Lebanon in 2014) [7].
- Saved Energy: 52712.85 MWh/year.
- Saved emission of CO2 from Fuel Oil: 35317.71 Ton of CO2/year.
- Saved fuel consumption from private generators: 36990 liters/day (6,658,200 liters/year).
- Saved cost of maintenance: 767,181$/year.
- Saved Cost of electricity and maintenance is 8,955,141$/year.
- LED lamps don't contain mercury (saved quantity is 1.59 kg/year).
- LED lamps are not sensitive to low temperature and humidity.
- Lifetime of LED lamps is not affected by the switching.
- LEDs are recyclable which is not the case of CFL or fluorescent lamps.
- LEDs have high performance even at the end of lifetime which is not the case of the CFL or fluorescent.

Etc…

- Creation of new job opportunities when the government creates new industries in the renewable energy sector and in the energy efficiency sector.

7.5 Evaluation of the Implementation

The budget needed to implement this project on the Lebanese scale only for schools and universities is equal to 120,408,000 $. The return on investment is 13.44 years (if the interest is equal to zero). So if this project is implemented now, then the saved energy for the upcoming 50 years is equal to 2,635.64 GWh (Fig. 1) which is an important energy on the Lebanese scale. The government can oblige all banks to give loan for a period of 10 years with a zero percent of interest in order to encourage all sectors and especially the educational sector to replace the current installation by LED lamps.

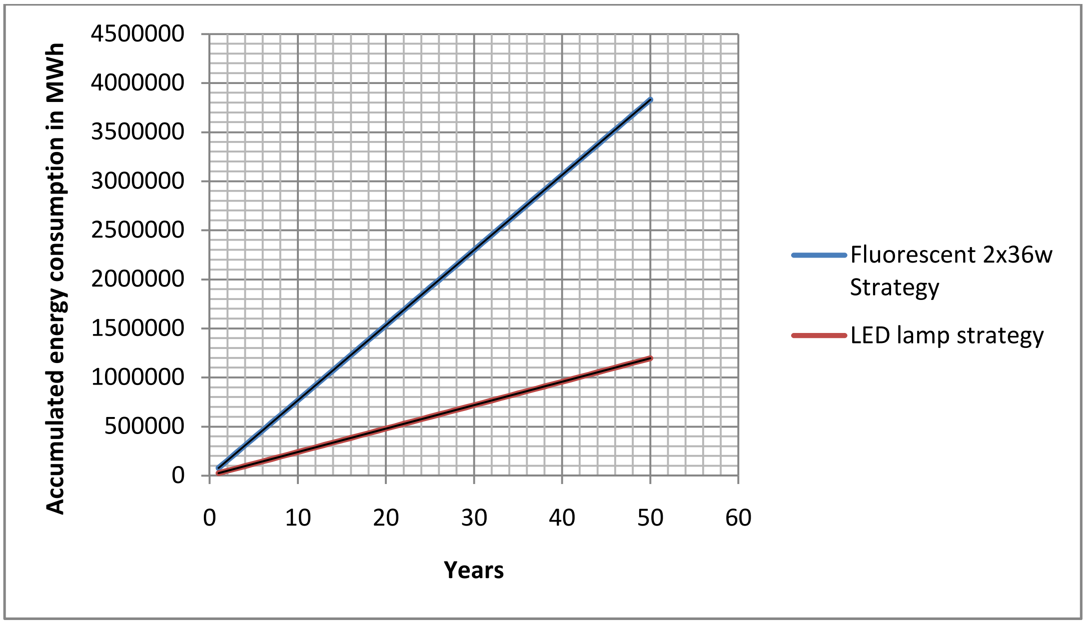

Fig. 1. Predicted saving energy during 50 years is equal to 2,635.64 GWh

7.6 Action Plan

The Lebanese government must do a serious action plan in order to oblige all schools and universities to replace the fluorescent lamps by LED lamps which will economize a lot of power and energy, reduce the emission of CO_2 and other toxic gases, and eliminate the emission of mercury which is very toxic for the health and for the soil and water. This will not just help schools and universities to reduce the consumed energy, but it will develop the economy of the country because the reduced energy and cost from this project can be used in other projects and to create industries which will develop the renewable energy sector in Lebanon and encourage all people to build efficient buildings and to save energy thus creating new jobs which revive the economy of the country.

The proposed plan in this paper is as following:

1. Government must take seriously the replacement of fluorescent lamps by LED lamps of high quality similar to the proposed one in this paper.
2. Create regulation that obliges all people to replace the existing lighting by LED lamps.
3. The government must oblige all banks to give loan with zero percent of interest for a period of 10 years for the payback.
4. Oblige all sectors to take loan from banks in order to do such project.
5. Increase taxes on the CFL and fluorescent lamps up to 400% in order to let the LED technology be competitive with the CFL and fluorescent technology.
6. Create industries that fabricate LED lamps with high technology.
7. Create industries concerning energy efficiency and all renewable energy sectors.
8. Stop importing incandescent lamps.
9. Stop importing low quality materials.

10. Eliminate taxes on high quality materials and equipment with very low power consumption.

7.7 Time Frame

The maximum duration of such project must not overpass 2 years from the time of declaring officially the regulations.

7.8 Institutions in Charge of the Implementation

The parties that are concerned in this project are the government, banks, industries, schools, universities, and all sectors.

8. CONCLUSION

In this paper, the authors present a comparative study between four different types of lamps (fluorescent 2x36W, CFL of type Philips, CFL of type Arcluce, LED of type ASTRA). This study emphasize the important of doing calculation using "DIALUX" software before selecting any type of lamps even if we consider this lamp is energy-saving. Moreover we have to take into consideration many indicators which are presented in this paper before buying any type of lamps. This study is a sample that helps all investors, owners, clients… to compare many types of lamps using indicators presented in this paper before buying them. We have to take also into consideration the impact on the environment such as the emission of the CO2, toxic gases, mercury.

In conclusion, the best choice of lamps in these days is the LED and of course a good quality and not a bad quality.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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