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ENERGY EFFICIENCY IMPROVEMNET IN HOUSES OF WORSHIPS

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ABSTRACT

Energy efficiency is a core of energy and environment policies, introducing a lot of benefits, containing many opportunities to decrease energy consumption, bill cost, fossil fuels and CO_2 emissions.
In Egypt, there are more than 115000 religion worships. Many of them are very inefficient when it comes to energy use.
The main step to implement EE options is energy audit.
The energy audit is carried out for a lot of RWs. It includes: observing the natural lighting, analysis of past energy bills, list for the type of loads (lamp, AC, fans, and water heaters), define savings potential, energy cost saving actions, reduction in gas emissions, and calculating the payback period.
Within RWs lighting makes up a significant part of electric energy consumption. Therefore, EE lighting technologies have been targeted by efficiency programs. There are many advanced energy saving technologies like; electronic ballasts, fluorescent tube (T5), and light emitting diodes (LEDs).
The most significant thing achieved by the auditors was the amount of money that will be saved due to implement options as lighting improvements and air conditioning control. The Egyptian Electricity Holding Company supports all customers, commercial, governmental, public utility…..etc. sectors to implement EE standards and codes for electric equipment and appliances.
This paper focuses on using LEDs for interior and external lighting of RWs, to verify the necessary illuminance, comfort conditions and energy savings.
The paper also presents: Training, capacity building and awareness for preachers, routine and preventive maintenance, simple, low cost and long-term energy saving tips that every RW can do to conserve energy, save money and reduce CO_2 emissions, lighting power density, the maximum lighting power per unit area of a building and classification of space function.

KEY WORDS
Energy efficiency, efficient lighting, LED technology, lighting in religion places.

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NOMENCLATURE

EE: Energy Efficiency.
EEHC: Egyptian Electricity Holding Company
RW: Religion worships
HPS: High pressure sodium lamps
GHG: Greenhouse gas emissions

1. INTRODUCTION

United Nations Development Program (UNDP) and Global Environment Facility (GEF) already have an electric energy strategy. The project "Improving Energy Efficiency of Lighting and Building Appliances" (IEEL&A) started in June 2011. The project has been providing EE light bulbs, in the form of LED, to replace; GLS, CFL…etc. in residential properties and public buildings. LEDs consume 85:90% less energy than standard GLS, while producing the same lumen output. Replacing GLS with LEDs is a simple way that significantly affects the GHS abatement and decreases the load power on energy infrastructure.

(IEEL & A) project is a national executed project funded by UNDP, GEF and the Egyptian government. The objective of the project is to improve the EE of end-use equipment, specifically building appliances and lighting systems manufactured, marketed and used in Egypt in order to facilitate a comprehensive market transformation of the Egyptian market towards the use of more EE lighting systems and electrical appliances.

(IEEL&A) implemented a number of specific activities in Cairo and Alexandria such as public building and street lighting, to use LED technologies, promote EE practices and see energy and financial savings.

2. LIGHTING SYSTEMS

Lighting consumes about 50% of electrical energy in RWs, and it is a main source of wasting energy. Excess heat and electricity can be decreased by implementing high efficient lighting technologies. Incandescent, fluorescent (longitudinal and compact) and high pressure sodium lamps are commonly used in RWs. These light sources are considered as an expensive source of light during winter, they also produce heat so during summer they force the air conditioning system to work harder and longer to provide the same degree of place comfort.
Modern electric technologies use LED lamps as a solution to overcome excess heat, large energy consumption and harmful effects on the environment. Table (1) represents the general lamps' characteristics. Before any retrofit options may be evaluated, it is first necessary to determine the types of measurements that should be considered.

Table 1 Characteristics of different lamps

Parameters	Incandescent lamp	Fluorescent lamp	HPS lamp	LED
Power (W)	3-500	5-100	35-1500	2.5- 350
Efficacy (lm/W)	15	60	Up to 120	Up to 140
Averaged rated life	755-1000	3000-12000	20000	25000-50000
Source optics	Point	Diffuse	Point	Point
Restrike time	Immediate	Immediate	1 minute	Immediate
Lumen maintenance	Good/ excellent	Fair/ excellent	Good/ excellent	Excellent

3. LIGHTING AND THE ENVIRONMENT

- Some types of lamps have been suggested to affect human health; they contain phosphor, or vapors such as mercury e.g.: CFLs, LFLs and discharge lamps. Throwing away these lamps should be in a good-ventilated area.
- The excessive noise from one or more:
  - The ballast is securely mounted.
  - Any fixture components are loose
- Lighting is typically the largest source of wasting heat inside public buildings.
- Glare is a measurement for discomfort feeling as a result of:
  - Object of excessive luminance
  - Excessive lighting contrast in the field of vision
  - High Difference in luminance levels
- GLS should never be used without suitable fixtures. Eyes will be damaged if they are viewed continuously for long periods.
  Because glare creates discomfort, loss of visual performance, and impaired visibility, it should be minimized wherever possible.
- The CO_2 emissions that results from using different types of fuel in electric power plants.

4. IMPROVING THE ENVIRONMENT

Reducing electricity demand leads to significant benefits for the environment. Emissions carbon dioxide, a major greenhouse gas, and sulfur dioxide would be reduced. Sulfur dioxide and nitrogen oxides are the primary causes of acid rain, and nitrogen oxides contribute to smog. Improving lighting efficiency decreases waste heat.

5. OPERATIONS AND MAINTENTANCE

There are a number of factors that lead to decreasing the light output and efficiency for all lighting systems such as: reduction in the lamp output light accumulated dirt on luminaires, and lamps burn out.
Proper maintenance of lighting system is significant to keep levels of illumination enough for productivity, visual comfort, safety and security. Planned and regular maintenance eliminates the number of required repairs, ensures safety of lighting systems, and keeps the required illuminance levels.
Regular maintenance includes:

- Cleaning the lamps or fixtures.
- Fixing and replacing non- effective lamps or fixtures.

Planned maintenance contains programs such as implementing group relamping every several years. Some problems in maintenance include:

- Poor reporting of the defined problems.
- Poor analysis of the problem.
- No work order system.
- No adequate maintenance training.

Good regular and planned maintenance saves on energy costs.

6. ENERGY EFFICIENCY LIGHTING

Improving EE for the interior lighting in RWs leads to achieving the necessary illuminance levels, as well as attaining comfort conditions, providing energy savings and reducing CO_2 emissions. EE is the core of electric energy, environmental protection and economics. Therefore, the benefits attributed to EE are multiple.
For example, a 25-100 W existing incandescent lamp, or 5-23 W CFLs lighting can be replaced by a 3-12 W LED lamp, yielding to energy savings up to 85%. To be compatible, EE lighting must provide the same quantity and quality of illumination as required for effective security lighting. Table 2 summarizes the benefits of EE improvements.

Table 2 Benefits of EE improvement

Environment	Economy	Energy
GHG emissions Local air pollution Health and safety	Asset value Public budgets Disposable income Employment Poverty alleviation Macro- economic impacts	Energy saving Energy delivery Energy prices Resource management Energy security Industrial productivity

7. THE PYRAMID OF EE

The pyramid of EE is prepared to:

- Help auditors prioritize stages
- Develop a right action plan
- Choose a clear EE lighting system
- Start a working point

Figure (1) represents the pyramid of EE and defines its stages.

8. ANALYSIS OF ELECTRIC BILLS

A detailed analysis for the electric bills is carried out for the previous 12 months, at least.
The importance of this analysis can be specified into:

- Figuring out the previous unknown energy losses by determining where energy is used.
- The proportionate use of each load source is specified in the electric bill when compared to the total bill

9. ENERGY AUDIT

In general, audit is a planned and documents activity performed to determine by investigation, examination, or evaluation of objective evidence, the adequacy of and compliance with establishes procedures, instructions, drawings, and other applicable documents, and the effectiveness of implementation [1].

The energy audit check the directions energy is currently used in RW facility and identifies some alternatives for reducing energy costs. The aims of energy audit are:

1- To understand how electricity is being used.
2- To identify technical tools to decrease energy consumption.

3- To study alternative techniques such as; improved operational and maintenance techniques, and/or new lighting system that could substantially decrease energy consumption and costs.
4- To identify an economic analysis for the suggested alternatives.
5- To provide optimum quality of light and maximize energy savings.

10. RWS ENERGY USE

The most common types of load in RWs can be categorized into:

- Lighting system:
  General lighting service lamps (GLS), blended, halogen, CFLs and LFLs used in interior lighting, while, metal halide and HPS fixtures used in exterior lighting.
- Ventilations system:
  Ceiling fans, wall fans, air curtains and air conditioners.

Table (3) summarizes the percentage ranges of lighting and ventilation systems, according to different types of systems for 48 RWs.

Table 3 Analysis of percentage ranges of lighting and ventilation systems for 48 RWs.

Range of loading %		Type of ventilation			
Lighting %	Ventilation %	Ceiling fan	Wall fan	Air curtain	Air conditioners
94 % : 66 %	6 % : 34 %	√			
92 % : 69 %	8 % : 31 %	√	√		
33 % : 8 %	67 % : 92 %	√	√		√
33 % : 13 %	67 % : 83 %	√	√	√	√

11. ENERGY USE INDEX (EUI)

The EUI is calculated from RWs' data survey such as; W/m^2 and kWh/m^2/year, it helps while determining the suitable EE lighting technologies and opportunities. The lighting power density (LPD) depends on the maximum lighting power and the area of the building i.e. W/m^2. Table (4) represents the LPD, using the ASHRAE/IENSA standard 90.1 space by space methods. Table (5) shows the lighting ratings guidelines according to [2], and it presents 7 W/m^2 when using LED lighting.

Table 4 LED using ASHRAE/ IENSA standard 90.1 space by space method [3]

Common space types	90.1-1999		90.1-2004/2007		90.1-2004/2007 less 10%	
	W/m^2	W/ft^2	W/m^2	W/ft^2	W/m^2	W/ft^2
Religious Buildings						
Worship- Pulpit Chair	56	5.2	26	2.4	23	2.2

Fellowship Hall	24	2.2	10	0.9	9	0.8

Table 5 Lighting rating guidelines [2]

W/m^2	Description
25	Worst (incandescent, old fluorescent with magnetic ballast (pre1990) lighting)
18	Bad (T12, direct illumin pre 2000)
14	Good (T8, electronic ballast, indirect, post 2000)
7	Best (LED lighting)

12. CASE STUDY (1)

Energy audit for 68 RWs was carried out, and LPD was calculated for each one. Figure (2) and table (6) represent the value of W/m^2 for these RWs.

Table 6 Results of W/m^2 for case studies

No of case studies	Range of W/m^2	Description
11	36.5 : 71	Worst
14	20.8 : 33.6	Bad/ Worst
23	12.7 : 19.9	Good/ Bad
20	4.4 : 11.52	Best/ Good

By comparing the data of tables 4, 5 and 6 the following notes were concluded:

- √ Only 20 RWs had best/ good lighting ratings.
- √ 9 RWs from 20 RWs had LPD lower than or equal 7 W/m^2.
- √ Large numbers of RWs require energy efficient lighting systems to reach the best lighting power density.

Other index reviews from detailed energy audit analysis for monthly electric bills is the monthly average energy consumption kWh/month, presented in table 7.

Table7 The average monthly consumption in kWh/month for RWs in different places in Egypt.

Place	Average monthly consumption (kWh/month)
South Cairo	1152

North Cairo	2954
Alexandria	500
Canal	820

The results of table 7 show that there are significant potential energy savings for RWs in North and South Cairo.

13. CASE STUDIES

The steps for RWs on-site energy auditing are classified into two steps:

Step 1: Defining the profile of the building, according to the types of different loads.
Step 2: Conducting a place by place lighting inventory; levels of illumination, lighting fixtures, type, size and number of lamps.

Table 8 represents the results of energy audit and the improvement value of the LPD in W/m^2 after replacing the existing lighting system to LED technology, for two RWs. Table 9 and 10 show the results of energy auditing and results of savings for the 103 RWs, respectively. Figures 3 and 4 represent the large number of lamps used in some mosques.

Table 8 Results of energy audit for two RWs.

Case study	**Types of the existing lamps**	**LPD for the existing lamps (W/m^2)**	**LPD LED Technology (W/m^2)**	**Percentage of energy savings**	**Reduction in CO_2 emissions**	**Payback period**
(1)	LFLs, CFLs, blended and sodium	13.2	5.6	68%	47 tons	3 years
(2)	LELs, CFLs, Halogen, GLS and metal halide	29	10	53%	18 tons	3 years

Table 9 Results of energy audit for 103 RWs.

Existing position		Suggesting position		no. of lamp	Total power of existing lamps (kW)	Total power of suggesting lamps (kW)
Type of lamp	rating (W)	type of lamp	rating (W)			
Incandescent (GLS)	25	LED bulb	4	213	5.325	0.852
	32		4	12	0.384	0.048
	40		4	3896	155.84	15.584
	60		6	1402	84.12	8.412
	100		12	2672	267.2	32.064
	120		12	20	2.4	0.24
	150		15	17	2.55	0.255
	200		24	76	15.2	1.824
	300		24	23	6.9	0.552
	500		54	18	9	0.972
Blended	160		15	88	14.08	1.32
Halogen	150		15	16	2.4	0.24
Metal halide fixture	250	LED fixture	100	91	22.75	9.1
	400		150	449	179.6	67.35
High pressure sodium fixture	250		100	76	19	7.6
	400		150	20	8	3

Power saving (kW)	645.34
Yearly energy savings (kWh)	1161604.80
CO_2 reduction (tons)	627.27
Payback period	7 months

Table 10 Results of savings for 103 RWs.

Training and capacity building is satisfied through holding two interactive workshops for more than 50 advocates of RWs, to know:

- The energy saving is a culture of life
- The advantages of EE
- Maintenance for building
- Current situation for energy consumption
- How to follow on the electric bills
- To promote the EE values
- Some case studies

14. CONCLUSION

Lighting consumes about 50% of the electrical energy in RWs, and it is a main source of wasting energy. Excess heat and electricity can be decreased by implementing high efficient lighting technologies. Modern electric technologies use LED lamps as a solution to overcome excess heat, large energy consumption and harmful effects on the environment. The most common types of load in RWs can be categorized into; lighting system and ventilation system.

Energy audit for 68 RWs was carried out, and LPD was calculated for each one and it was concluded that; only 20 RWs had best/ good lighting ratings, 9 RWs from 20 RWs had LPD lower than or equal 7 W/m^2 and large numbers of RWs require energy efficient lighting systems to reach the best lighting power density.
On-site energy auditing for two RWs, and the result was an improvement in the value of the LPD W/m^2 after replacing the existing lighting system to LED technology.
Energy audit was done for 103 RWs and the results of savings were shown.
Improving EE for the interior lighting in RWs leads to achieving the necessary illuminance levels, as well as attaining comfort conditions, providing energy savings and reducing CO_2 emissions. EE is the core of electric energy, environmental protection and economics. Therefore, the benefits attributed to EE are multiple.

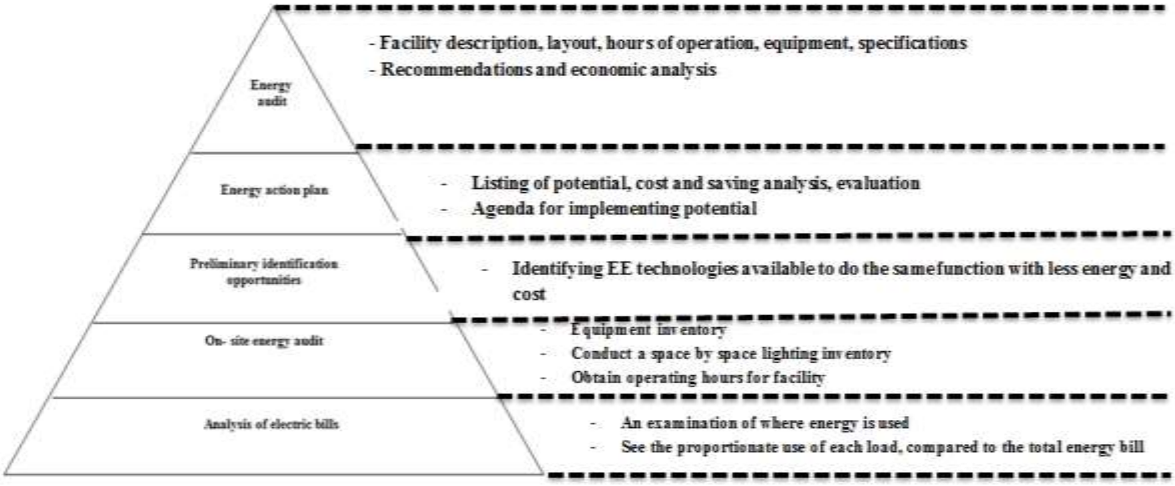

Fig (1) EE pyramid

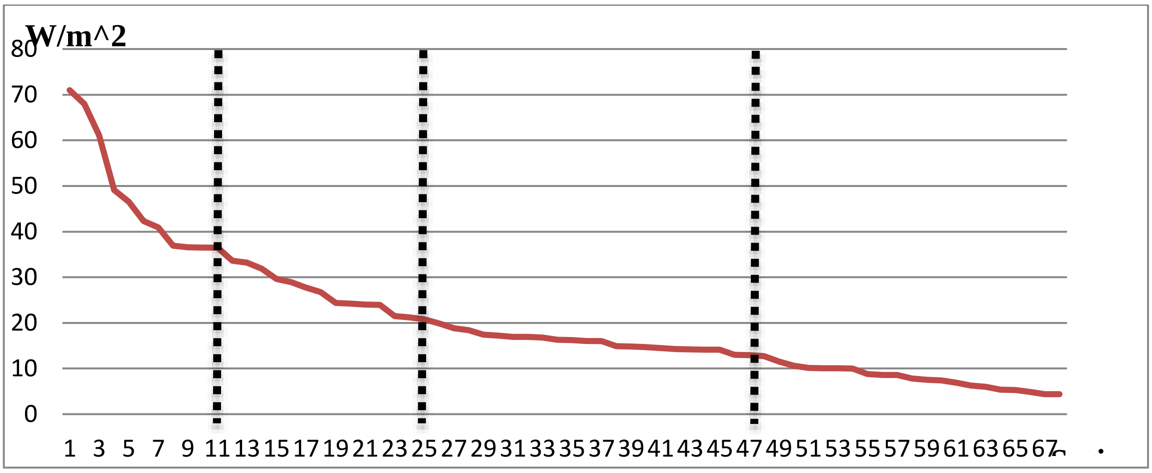

Figure 2 W/m^2 for the studied 68 RWs

Fig 3 large chandelier in a mosque contains 80 lamps

Fig 4 Exaggerated lighting decorations

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