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Economic Model for Calculating the Global Saving Norm of Replacement High-Intensity Discharge Lamps with LED Lamp in Oil and Gas Plant

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***Abstract*—This paper is an extension work to previous research that calculates the saving norm of replacement HPS Street Lighting by LED fixtures in access road of gas production company at GCC. In this paper we introduce a novelty in economic model to consider the replacement of different types of high-intensity discharge lamps (HID) by LED lights. The global saving norm and the payback indicator are determined based on two main aspects; "Company Benefits", in which the Gas Company can gain it directly, and "National Benefits" that can be achieved by creating better gas sales opportunity for the county and by the reduction of the CO2 emission and hence the pollution.**

Keywords— LED lighting; LED Economics; LED verses HID; Lighting Economic Norm Introduction

I. Introduction

The High-intensity discharge lamps (HID lamps) are a type of electrical gas-discharge lamp which produces light by means of an electric arc between tungsten electrodes housed inside a translucent or transparent fused quartz or fused alumina arc tube. This tube is filled with noble gas and often also contains suitable metal or metal salts. The noble gas enables the arc's initial strike. Once the arc is started, it heats and evaporates the metallic admixture. Its presence in the arc plasma greatly increases the intensity of visible light produced by the arc for a given power input, as the metals have many emission spectral lines in the visible part of the spectrum.

Many lighting application use HID bulbs for the main lighting systems, although some applications are now moving from HID bulbs to LED because of the LED advantages [1].

By about 2010 LED technology came to dominate the outdoor lighting industry; earlier LEDs were not bright enough for outdoor lighting. A study completed in 2014 concluded that color temperature and accuracy of LED lights was easily recognized by consumers, with preference towards LEDs at natural color temperatures [2]. LEDs are now able to match the brightness and warmer color temperature that consumers desire from their outdoor lighting system.

In [3], after comparing the power characteristics and lighting characteristics, it is clearly stated that using LED lighting to replace the traditional lighting devices are possible. Protection circuits such as current, voltage and temperature are needed to increase the reliability. In order to make such mission become truth, the first important thing should be done is to lower the unit cost and secondary to have a proper and reliable power circuit with less loading and electrical faults [4]. Also suitable optics is needed to control the light pattern from the LEDs including focus, diffusion, reflection, and light amplification.

Several paper carried out economic analysis of replacement different light fittings with LED. However, none of these paper has considered the economics f replacement the HID lamps by LED lamps in oil and gas plant. Moreover, none of these papers has presented any type of economic index to support such type of lighting projects, except [1], which limited the research the replacement of only HPS type used in access road of a gas production company.

In [5]. The author concentrated only on "indoor Lighting", and the paper proposed a decision support system for techno-economic evaluation of indoor lighting systems with LED luminaires.

In [6], the research compares the life cycle costs (LCCs) of two typical alternatives in current road lighting: the HPS and LED luminaires. They are compared considering the road lighting design criteria, but the aesthetics and visual attractiveness are excluded from the comparison. The comparison and the results result have considered only the direct energy operating cost.

The author in [7] provides Economic cost analysis comparison between LED and HPS flood lights for an outdoor design but using using solar PV as a power supply.

In [8], the paper examines the feasibility of LED lamp in replacing the conventional fluorescent lamp. Analysis and comparison have been carried out on the two lighting systems in terms of electrical and photometrical performance. The study did not cover any HID outdoor lighting.

In [1], the paper analyses the Company and National economic benefits due to the high service life of the LED light fittings (up to 100,000 Hours) and low power consumption compared with HPS. The paper highlights other benefits such as reduction of the CO2 emission and lighting pollution lighting as well as sales gas opportunity. From the economic study, typical Annual Saving Norm saving is calculated and it is found to be $433.36/kW. This Norm is very important to evaluate the future economics of projects that shall consider replacing the existing HPS lighting by LED lighting. However, the paper has only considered 400W HPS lighting case.

The first goal of this paper is to discuss the economic benefits of replacing outdoor different type of HID lights with different rating installed in an existing oil and gas plan, with suitable equivalent number of LED lighting fittings, to provide even better lighting effect level, without changing the lighting poles. The second goal is to determine four economic indicators "Global Total Saving Norm", "Global Company Saving Norm"**,** typical "Total Payback Period" and typical "Project Annual Return on Investment", These four indicator are calculated based on two main aspects: "Company Benefits", in which the Company can gain it directly, and "National Benefits" that can be achieved by creating better gas sales opportunity for the county and by the reduction of the CO2 emission and hence the pollution.

In Section-II, international and national directives toward the replacement of inefficient light fittings are highlighted. Then, in Section-III, comprehensive economic study is introduced to replace 241 pieces of 150W Metal Halide, 103 pieces of 400W HPS lighting, 20 pieces of 1000W MH lighting and 162 pieces of 70W Bollard lighting with equivalent number of LED lighting fittings. In Section IV economic discussion is provided. Finally, summary, conclusion and recommendation are provided in Section V. template is used to format your paper and style the text. All margins, column widths, line spaces, and text fonts are prescribed; please do not alter them. You may note peculiarities. For example, the head margin in this template measures proportionately more than is customary. This measurement and others are deliberate, using specifications that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

II. International & National Directives

European Commission issued the Regulations EC No. 245/2009 for tertiary lighting products on 18 March 2009. On the basis of these Regulations, about 1 billion lighting products have to be replaced by LED type by the year 2015 only in the area of the EU, which translates to 100 million street lamps for street lighting and industry. The remaining 900 million refer to neon lamps.

Similarly, the Energy Information and Security Act of 2007 began the process of restricting the sale of inefficient lamps in the US. By 2012, with a few exceptions, the result of the legislation will be that inefficient incandescent lamps cannot be sold. [1]

In GCC Oil and Gas Companies, many case studies and projects have been carried out to use the LED lighting technology instead HID technology. The studies have proved appreciated saving in power and maintenance cost [9]. However, these studies did not include the "National Benefits" that can be achieved by creating better gas sales opportunity for the county and by the reduction of the CO2 emission and hence the pollution. Also, these studies did not provide any indices or norms to be used in similar future applications to support project management decisions.

III. Economic Study To Calculate The Norms

The following comprehensive economic study is carried out to estimate the financial benefits of replacement of outdoor HID (High intensity discharge) lights in an oil and gas plant by the equivalent LED (Light Emitting Diodes) lighting fixture. The Study has considered the following factors:

A. *Company Benefits:*

a) The initial cost of the replacement the lighting fixtures.

b) The energy saving.

c) The maintenance cost.

B. *National Benefits:*

d) Natural Gas Sales opportunity

e) Pollution Cost

In Company Benefits, calculation for "Luminaire Cost", "Power Consumption" and "Maintenance Cost" are given based on offers and prices collected on 2015 -2016 from different bidders, contractors and suppliers to find the lowest prices.

In National Benefits, two benefits are considered. First benefit is the gas sales opportunity that will be gained from the reduction of the power consumption in case LED light is used. Natural gas valued using the wholesale price of $4.618/MMBtu based on US Energy Information Administration Henry Hub/NYMEX futures prices; Equivalent energy rate of 5.6 ¢/kWhr is used to value the energy produced over 10 years, assuming 1% annual escalation factor and Euro to USD exchange rate of 1.2 [1][4]. Accordingly,

$$\text{Annual Natural Gas Sale Opportunity} = 1.2 \times 0.056 \times \Delta\ \text{kWhr}\ \$ \quad (1)$$

Where Δ kWhr is the reduction in the power consumption.

However, the second benefit is the cost saving due to the reduction of the CO2 emission, and hence less pollution. Carbon credits based on current market is 6 euro/ton. Where, CO2 emission is considered to be 0.83 kg/kWh [1][4]. Assuming Euro to USD exchange rate of 1.2, the annual saving in pollution reduction can be calculated as following:

$$\text{Annual Saving in Polution} = \frac{0.83 \times \Delta\text{kWhr} \times 6 \times 1.2}{1000}\ \$ \quad (2)$$

The economic study is categorized based on HID lamp type that is needed to be replaced in the plant under the study. Typical study is summarized in the following Table-1 for 150W Metal Halide luminaire replaced by 65W GREE LED luminaire. Where

$$\text{Company Saving N} = \frac{\text{Annual Company Net Saving}}{\text{Total kW for the Replaced HID Lighting}} \quad (3)$$

$$\text{Total Saving N} = \frac{\text{Total Net Average Anual Saving}}{\text{Total kW for the Replaced HID Lighting}} \quad (4)$$

TABLE I. SUMMARY OF ECONOMIC STUDY FOR REPLACEMENT OF 150 W METAL HALIDE LUMINAIRE BY 65W LED LUMINAIRE

Company Benefits				
I.	**LUMINAIRE PRICE ANALYSIS**			
S/N	**Description**	**150W MH Metal Halide [10]**	**65W CREE Luminaire [11]**	**Remarks**
1	Initial Fixture cost	$227.52	$449.59	
2	Total quantity	241	241	
3	Total quantity Cost	0	108351.4986	
4	Cost/lamp manpower, crane, dumping etc…	108.9918256	108.9918256	This estimate taking into consideration replacement cost, man power, special vehicle, manpower to divert/block traffic, cost of loading / unloading and installation
a	Therefore initial investment for LED	0	**$134,618.53**	Additional investment for using LED luminaire.
II.	**POWER CONSUMPTION ANALYSIS**			
S/N	**Description**	**150W MH Metal Halide [10]**	**65W CREE Luminaire [11]**	
1	Wattage per fixture	150	72	System Wattage includes losses
2	No of fixtures in the lighting circuit	241	241	
3	Total power consumed (kW)	36.15	17.352	
4	Hence total Power consumed per year(kWHr)	145142.25	69668.28	Average daily operating time is considered 11 Hours
5	Cost per kWHr	0.026948229	0.026948229	As agreed with Utility
6	Annual cost	3911.326574	1877.436755	
	Service Life Range	16000-20000	60000-100000	
7	Average Service life (Hrs)	18000	80000	
b	Therefore the saving in 10 Years	**$20,338.90**		
III.	**MAINTENANCE COST SAVING ANALYSIS - LAMPS**			
S/N	**Description**	**150W MH Metal Halide [10]**	**65W CREE Luminaire [11]**	**Remarks**
	Service Life Range	16000-20000	60000-100000	
1	Average Service life (Hrs)	18000	80000	
2	Number of Lamps change cycle in 10 Year	2.230555556	0	LEDs have no downtime against MH lamps which fail arbitrarily
3	Total No. of Lamps	538	0	
4	Cost/lamp manpower, crane, dumping etc	108.992	0	This estimate taking into consideration new lamp cost, man power, special vehicle, manpower to divert/block traffic, cost of loading / unloading and installation.
c	Therefore savings in lamp maintenance in 10 Years	**$181043.6**		
IV.	**MAINTENANCE COST SAVING ANALYSIS - IGNITORS / BALLASTS / CAPACITORS**			
S/N	**Description**	**150W MH Metal Halide [9]**	**65W CREE Luminaire [10]**	**Remarks**
1	Rated life (Hrs)	15000	N/A	
2	Life in 10 years	2.676666667	N/A	
3	Total No. of Ballasts	241	N/A	
4	Thus component to be replaced in 10 Years	645	N/A	
5	Cost/lamp manpower, crane, dumping etc…	81.74386921	N/A	This estimate takes into consideration new ballast cost, man power, special vehicle, manpower to divert/block traffic, cost of loading / unloading and installation.
c	Therefore savings in component maintenance in 10 Years	**$52,731.06**	N/A	

SUMMARY OF 10 YEAR COST SAVINGS USING LED LIGHT FITTINGS		
a	**INITIAL INVESTMENT ON LED**	**$134,618.53**
b	**ENERGY**	**$20,338.90**
c	**MAINTENANCE - LAMPS**	**$181043.6**
	MAINTENANCE - COMPONENTS	**$52,731.06**
	TOTALL COST SAVING IN 10 YEARS	**$254,113.36**
	Total Average Annual Saving	**$25,411.336**
Company Net Saving in 10 Years		**$119,495**
Annual Company Net Saving		**$11,949.5**
National Benefits		
V. Natural Gas Opportunity Cost:		
d	Natural gas valued using the wholesale price of $4.618/MMBtu based on US Energy Information Administration Henry Hub/NYMEX futures prices; Equivalent energy rate of 5.6¢/kWh used to value the energy produced over 10 years, assuming 1% annual escalation factor.	**$5,071.85**
VI. Pollution cost		
e	Carbon credits –based on current forward market @ 6 euro/ton, CO2 emission in kg/kwh: 0.83, Euro to USD exchange rate of 1.2.	**$451**
National Benefit Saving in 10 Years		**$5,522.887**
Total Benefits		
Total Saving in 10 Years Operation		**$125017.88**
Total Net Average Annual Saving		**$12501.788**
Company Saving Norm = Annual Saving / kW (3) [1]		**$330.55**
Total Saving Norm = Total Net Average Annual Saving / kW (4) [1]		**$345.83**
Economic Analysis		
Company Payback Period in Years (Initial investment for LED/Annual Company Net Saving		**11.27 Years**
Company Annual Return on Investment "ROI" in Percentage		**8.88%**
Total Payback Period in Years (Initial investment for LED/Annual Company Net Saving		**10.77 Years**
Total Annual Return on Investment "ROI" in Percentage		**9.29%**

Similar to the typical economic study that is carried out for 150W Metal Halide lighting, economic study is done for the remaining types of lighting; 103 pieces of 400W HPS lighting, 20 pieces of 1000W MH lighting and 162 pieces of 70W Bollard lighting. Summary Tables are provided hereinafter to show the Total Benefit and the Economic Analysis for these luminaire types.

TABLE II. REPLACEMENT OF 400W HPS LIGHTING WITH (100-130) W CREE LUMINAIRE

Total Benefits:	
Total Net Average Annual Saving	$14,899.66
Company Saving Norm = Annual Saving / kW (3) [1]	$184.02
Total Saving Norm = Annual Saving / kW (4) [1]	$360.29
Economic Analysis	
Payback Period in Years	4.632 Year
Annual "ROI" in Percentage	21.59%

TABLE III. REPLACEMENT OF 1000W MH LIGHTING WITH (426)W CREE XAK LUMINAIRE

Total Benefits:	
Total Net Average Annual Saving	$2,543.09
Company Saving Norm = Annual Saving / kW (3) [1]	$ 107.15
Total Saving Norm = Annual Saving / kW (4) [1]	$127.15
Economic Analysis	
Payback Period in Years	10.93 Years
Annual "ROI" in Percentage	19.15%

TABLE IV. REPLACEMENT OF 70W BOLLARD LIGHTING WITH (34) W CREE EDGE PATHWAY LUMINAIRE

Total Benefits:	
Total Net Average Annual Saving	$9,291.03
Company Saving Norm = Annual Saving / kW (3) [1]	$799.05
Total Saving Norm = Annual Saving / kW (4) [1]	$819.31
Economic Analysis	
Payback Period in Years	8.657 Year
Annual "ROI" in Percentage	11.55%

Following Table V summarizes the main Project Economics indicators that can be used as good guide line for future similar projects that consider the replacement of HID lighting by LED Lighting.

TABLE V. PROJECT ECONOMICS

Project Total Investment	**$339,550.41**
Project Total Average Annual Saving	**$39,235.9**
Project Total Payback Period (Average)	**8.654 Year**
Project Annual Return on Investment "ROI" in Percentage	**11.55%**

IV. Discussion

Based on the Saving Norm calculated for individual luminaire type in the above Tables I, II, III &IV, the Global Saving Norm can be calculated based on the following

$$\text{Global Saving Norm} = \frac{1}{n}\left(\sum_{1}^{n} Norm_n\right) \quad (5)$$

Where "n" is the number of replaced lighting types in the study.

Using equation (5), the calculated Global Company Saving Norm is (355.19$/kW). However, the calculated Global Total Saving Norm is ($413.0/kW). Comparing the last value with the Saving Norm ($433.37/kW) calculated in [1] for the replacement of only 400W HPS light fixture with LED light fixture, it is noticeable that the new calculated Saving Norm is less by approximately 4.71%. This shows consistency of the results, however, it is obvious that in Global Total Saving Norm, more information is used to calculate this generalized norm number which make it more valid to be used as a better indicator for any project that need to evaluate the average benefit of HID lighting replacement by LED lighting.

From Table III, it can be concluded that replacement of HPS lighting by LED lighting have the highest National economic value. Therefore, it is highly recommended to use LED lights instead of HPS lights in oil street lighting applications.

It is also observed from Table IV that replacement Bollard Light Lamps by LED Lamp in oil and gas plant have highest economic value because of the very short lifetime Bollard Light Lamps compared with LED lifetime.

In Table V, Project main economic indicators are illustrated with very attractive total payback period of 8.654 years and Project Annual Return on Investment of 11.55% which is higher approximately 10 times than the international bank rate for dollar deposit. This indicator supports the decision of investment in such scope of work.

V. Summary and Conclusion

In this paper, comprehensive economic study is carried out to calculate the Global Saving Norm for the replacement of High-intensity discharge lamps with different types by LED lamp in an Oil and Gas plant, which includes also the operational cost per year. The paper considered Company direct benefits and National indirect benefits in evaluating project economic indicators and in calculating the Global Saving Norm as well. The result is compared and validated with previous research effort. Four important economic indicator were provided in this paper; Global Total Saving Norm **($433.37/kW),** Global Company Saving Norm **($355.19/kW),** typical total payback period of **(8.654 year)** and typical Project Annual Return on Investment of **(11.55%).** These four figures are important for both project decision makers and for cash-flow controllers.

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