Typical Economic Model for Calculating the Saving Norm of Replacement HPS Street Lighting by LED Fixtures in Access Road of Gas Production Company at GCC

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***Abstract*—This paper illustrates the advantages of the LED as a valid option to replace the HPS street lighting. Economic model is introduced to determine the Annual Saving Norm for replacing access road HPS light fitting installed in a GCC gas production company by LED fixtures. This Annual Saving Norm is calculated based on two main aspects. "Company Benefits", in which the Gas Company can gain it directly. "National Benefits" that can be achieved by creating better gas sales opportunity for the county and by the reduction of the CO_2 emission and hence the pollution.**

***Index Terms*—LED lighting, LED Economics, LED street Lighting, LED verses HPS**

I. Introduction

HPS lamps were introduced around 1970 and are one of the more popular street lighting options and the most efficient light source when compared to mercury vapor and metal halide lamps (on a 'lumen/ watt' scale). The disadvantage is that they produce a narrow spectrum light with a sickly yellow color. These lights have a very low color rendering Index and do not reproduce colors faithfully. These lights do not find favor with police departments as it is difficult to determine the color of clothes and vehicles of suspects from eye witness accounts in the event of a crime. Color-corrected sodium vapor lamps exist but are expensive. These "color corrected" HPS lamps have lower life and are less efficient.

Another issue of HPS lights is that they contain 1 to 22 mg of mercury for a 100 watt bulb with an average of 16 mg per bulb. They also contain lead. Unsafe disposal of these bulbs can lead to significant exposure of human beings and wild life to mercury contaminated water and food. Issues with mercury contamination and customer preference for full spectrum light has been fuelling the replacement of these lights particularly in areas like self-managed residential complexes where people can directly pay for the quality of light.[1,2]

Light emitting diodes (LED) are rapidly developing in light output, color rendering, efficiency, and reliability. Achieving good level of maintenance-free in harsh environment, while keeping product competitive, is the largest challenge which only few manufacturers manage to achieve. The latest high quality LED technologies are already exceeding all other available technologies by all technical parameters. According to its numerous advantages, even higher initial cost quickly pays for itself due to vastly reduced cost of electricity and maintenance. But to fully benefit from the outstanding advantages it is important to educate and recognize the difference between low quality and latest state of the art LED technologies, since low quality LED alternatives have quickly spread all over the world [1,2].

In this paper Section II general introduces the main benefits of high quality LED lighting. In Section III, International and GCC directive of using different types of lighting fixtures is discussed. Section IV illustrates comprehensive economic study based on actual project to estimate the financial benefits of replacement 1131 number of 400W HPS (High Pressure Sodium) Access Road lighting fixtures by 100W LED (Light Emitting Diodes) lighting fixture to calculate the Saving Norm. Then Conclusion is given in Section V

II. General benefits of High Quality LED Street Lights

Below listed benefits of LED street lighting are related only to latest, high quality LED street lights [1],[2]:

A. *Less energy consumption*

LED street lights use 40-80% less electricity and have at least 5 times the life expectancy than regular High Pressure Sodium (HPS) fixtures. LED lamps are 7 times more energy efficient than incandescent and twice as efficient as fluorescent lamps.

B. *Higher efficiency and low light pollution due to directional light*

LED street lights with a lower lumen output can replace conventional lamps with a higher output. For example, a 30W LED street light can often replace an 80W High Pressure Sodium lamp. The reason for this is directionality. LED street lamps are very directional and the light output is much more than other street lamps. Also there is little or no hot spot under the LED lamp. The light emitted from the LED lamp is directed downwards, spread throughout the entire area it covers. This means that a lower amount of light is needed to properly illuminate the area. This also dramatically reduces glare and light pollution which affects the mood of human beings, navigation in birds and insects, mating behavior in animals and flowering in plants.

C. *Long life – up to 100.000 hours*

LED street lights last much longer than conventional lamps (4 to 8 times longer). This result in less expense in

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replacing the lights themselves but also the labor to replace the lamp is needed less often. This provides a great cost savings by itself.

Also the loss of brightness or lumen depreciation is slower over the life of an LED lamp than that of sodium or other lamp. So not only does the LED have a longer life span than the conventional lamp, but it stays brighter longer than other lamps. The long life span reduces maintenance expenses and makes these bulbs particularly suitable for difficult to reach locations and for streetlights where maintenance costs can be significant.

D. Great operating characteristics

LED operates at efficiently at low and high temperatures, and unaffected by on/off cycling. This makes them safer and efficient in special indoor applications such as refrigerator lights and cold room lights, and better for applications requiring frequent switching on and off lights. These bulbs are shocks and vibrations resistant making them the best choice for places like bridges.

E. Reducing carbon footprint

The carbon footprint of LED street lights is smaller than other lights due to lower energy usage. Moreover LEDs last 4 to 8 times longer than any other bulbs, further reducing the carbon footprint of manufacture over the life time.

F. Dark-sky friendly

Because of the directional light, light is carefully distributed exactly where it is meant to go and therefore there is no or little light which is wasted by illuminating the night sky. This is a considerable plus especially if the local community has a Dark-sky Initiative.

G. Natural light specter – Color Rendering Index

LED street lamps with color temperature 3.500-4.200 K are rendering more natural light than the yellow of sodium lamps or green of fluorescent streetlights. Also no UV or IR radiation is emitted from the LED street lamps. Color rendering index (CRI) is high (80-90) and displays natural colors of illuminated objects.

H. Free of harmful substances and lower environmental impact

LED luminaires contain no harmful substances, like mercury, lead or other hazardous chemical and gasses. Spent LED lamps can be thrown away without any special handling or disposal requirement, since they are recyclable and environmentally friendly. Other light often have hazardous materials such as lead and mercury which require special handling and waste management procedures which have both economic and environmental costs.

I. Visibility in rain and fog

Philips Company shows in their research that visibility in rain and fog is defined by two parameters: the amount of light scattering and the penetration of the light. The water droplets in the fog acts like tiny mirrors and causes unwanted light scattering (or glare) that affect the vision of road users.

White LED light produces less-glare than yellow HPS light in rain and fog conditions. Also the penetration factor is favorable for LED. However, some research shows that LED road lamps achieve greater light penetration through fog [4].

J. Easily controllable

The light is easily controllable with intelligent systems. The light can be turned on and off instantly and can be dimmed for added energy savings at dawn, dusk, and also during hours of low traffic. Switching on-off and dimming does not affect the life-time of the luminaire as in the case of fluorescent lights [5].

In [6], 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. Also suitable optics is needed to control the light pattern from the LEDs including focus, diffusion, reflection, and light amplification.

III. 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 [7].

IV. Economic Study To Calculate The Saving Norm

The following comprehensive economic study is carried out to estimate the financial “Company Benefits” and “National Benefits” of replacement 1131 number of 400W HPS (High Pressure Sodium) Access Road lighting fixture by 100W LED (Light Emitting Diodes) lighting fixture. The Study has considered the following factors:

- Initial cost of the replacement the lighting fixtures.
- Energy saving.
- Maintenance cost.
- Natural Gas Sales opportunity
- Pollution Cost.

A. Company Benefits:

In this section, calculation tables 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.

Table I illustrates the Luminaire Price Analysis based on prices collected from lower bidder.

TABLE I: LUMINAIRE COST ANALYSIS

S. No	DESCRIPTION	HPS 400W	LED 100 LED
1	INITIAL FIXTURE COST	217.80	598.96
2	TOTAL QUANTITY	1131	1131
3	TOTAL QUANTITY COST	0	677429.89
4	COST/LAMP MANPOWER, CRANE, DUMPING ETC	108.90	108.9
A	**INITIAL INVESTMENT FOR LED**	**0**	**$800,599**

Table II analyses the power consumption cost for 20 years. The kWh rate is obtained from special power agreement between the utility and the oil and gas sector.

TABLE II: POWER CONSUMPTION ANALYSIS

S. No	Description	HPS	LED
1	Wattage per fixture	460	107
2	No of fixtures in the lighting circuit	1131	1131
3	Total power consumed (kW)	520.26	121.017
4	Power consumed per year(kWhr)	2088843.	485883.2
5	Cost per kWhr	0.026926	0.026926
6	Annual cost (11hr/day)	56244.66	13082.99
7	Service Life Range	16000-20000	60000-10000
8	Average Service life (hrs)	18000	80000
9	Changing Cycle (20Year)	19.9	0
10	Cost in 20 Year (80000 Hour)	305115.9	260682.4
B	**Saving in 20 Years**	**$860,008**	

Table III and Table IV and summarizes the maintenance cost saving for 20 years that can be obtained due to the long life of the LED and from the reliability of the LED fixture components.

TABLE III: MAINTENANCE COST SAVING - LAMPS

S. No	Description	HPS	LED
1	Number of Lamps change cycle in 20 Year	4.444	0
2	Total No. of Lamps	5027	0
3	Cost/lamp manpower, crane, dumping etc.	108.9	0
C	**Savings in lamp maintenance in 20 Years**	**$1,642,363**	0

TABLE IV: MAINTENANCE COST SAVING – IGNITER/BALLAST/CAPACITORS

S. No	Description	HPS	LED
1	Rated life (Hrs)	10000	N/A
2	Life in 20 years	8	N/A
3	Total No. of Ballasts	1131	N/A
4	Component to be Used	9048	N/A
5	Cost/lamp manpower, crane, dumping etc.	81.67	N/A
D	**Savings in component maintenance in 20 Years**	**$739,014**	**N/A**

Usually, when HPS lights are replaced by LED lights there is good chance to use the replaced HPS elsewhere instead of getting rid of them. In this paper we assumed that the utilization factor is 0.5. Table V illustrates the saving that can be obtained by utilizing the used HPS light fittings.

TABLE V: LUMINAIRE COST ANALYSIS – REUTILIZATION OF THE REPLACED HPS LIGHT FITTINGS ELSEWHERE.

S. No	Description	HPS	LED
1	Number of Fitting to be re-utilized	1131	N/A
2	HPS Light Fitting cost	217.80	N/A
3	Utilization Factor	0.5	N/A
E	**Cost Saving**	**$123,169**	**N/A**

From above, we can summarize the cost saving by replacing 1131 HPS light fittings by LED fitting as shown in Table VI

TABLE VI: POWER CONSUMPTION ANALYSIS

A	INITIAL INVESTMENT ON LED	$800,599
B	ENERGY	$860,008
C	MAINTENANCE - LAMPS	$1,642,363
D	MAINTENANCE - COMPONENTS	$739,014
E	MAINTENANCE - REUTILIZATION OF THE REPLACED LIGHT FITTINGS	$123,169
F	TOTALL COST SAVING IN 20 YEARS	$3,364,555
G	**NET SAVING IN 20 YEARS**	**$2,563,956**

However in this company the plant is designed to last minimum 30 years. Therefore, the following economics analysis can be given (Table VII).

TABLE VII: ECONOMIC ANALYSIS

Payback Period in Years	:	4.74
Annual "ROI" in Percentage	:	420%
Company Saving in 20 Years	:	$2,563,956
Company Saving in 30 Years	:	$3,784,350

B. National Benefits:

In this section we will consider two benefits that the country shall obtain from replacing the HPS light by LED light.

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 used to value the energy produced over 10 years, assuming 1% annual escalation factor. Accordingly,

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

Where Δ kWh is the reduction in the power consumption.

$$\Delta\text{kWh} = 2088843 - 485883.2 = 1602960.645\ \text{kWhr} \quad (2)$$

From (1) and (2),

$$\text{Annual Natural Gas Sale Opportunity} = 89{,}765.80\,\$ \quad (3)$$

However, the second benefit is the cost saving due to the reduction of the CO_2 emission, and hence less pollution.

Carbon credits based on current market is 6 euro/ton. Where, CO_2 emission is considered to be 0.83 kg/kWh [7]. Assuming Euro to USD exchange rate of 1.2, the annual saving in pollution reduction can be calculated as following:

$$\text{Annual Saving in Polution} = \frac{0.83 \times \Delta \text{kWhr} \times 6}{1.2 \times 1000} \quad (4)$$

$$\text{Annual Saving in Polution} = 6{,}652.29 \ \$ \quad (5)$$

Based on Equations (3) and (5), the national benefits can be calculated for 20 years and 30 years of operation (Table VIII).

TABLE VIII: THE ARRANGEMENT OF CHANNELS

National Benefit Saving in 20 Years	**$1,928,361.66**
National Benefit Saving in 30 Years	**$2,892,542.48**

From Table VII and Table VIII the total benefit can be summarized in Table IX as following:

TABLE IX: TOTAL BENEFIT SUMMARY

Total Saving in 20 Years Operation	**$4,492,317.72**
Total Saving in 30 Years Operation	**$6,676,892.04**
Total Average Annual Saving	**$225,458.20**

Now, in order to calculate the "Saving Norm- N_{saving}" of Replacement HPS Street Lighting by LED Fixtures, let us first define the N_{saving} as the annual saving amount per total kW for the replaced HPS lighting;

$$N_{saving} = \frac{\text{Total Average Anual Saving}}{\text{Total kW for the Rellaced HPS}} \quad (5)$$

Based on Equation (5), typical N_{saving} of **$433.36/kW** can be determined for GCC Oil and Gas Sector to be used as an indicator for future projects that shall be run the to replace HPS street lighting by LED Lighting.

V. CONCLUSION

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), low power consumption compared with HPS lighting and sales gas opportunity. The paper highlights other benefits such as reduction of the CO_2 emission and lighting pollution. From the economic study, typical Annual Saving Norm N_{saving} was calculated and 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.

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