The Nucleus 51, No. 3 (2014) 373-378

www.thenucleuspak.org.pk

The Nucleus

ISSN 0029-5698 (Print)
ISSN 2306-6539 (Online)

Case Study of Energy Saving in an Industrial Setup by Replacing Conventional Bulbs with LED Lights

S. Khanam and A. Hanif*

Electrical Engineering Department, Wah Engineering College, University of Wah, Wah Cantt. Pakistan

(Received April 28,2014 and accepted in revised form August 08, 2014)

Lighting accounts for roughly one-fifth of global electricity consumption. The demand for energy is increasing day by day with increase in population, change in life style, and change in technology. This growing demand led to energy crisis which is the biggest threat for economic stability for developing countries like Pakistan. This crisis has badly affected the everyday life and industry. To overcome energy shortfall one solution is to focus on energy conservation. Significant energy savings can be achieved by reducing energy consumption by artificial lighting which has potential of energy saving by using efficient lighting technologies such as Light Emitting Diodes (LEDs). A case study is carried out for an industrial setup to compare the performance, suitability and financial effects of conventional bulbs and LED lights in an industrial setup. A new lighting scheme has been designed by using DIALux 4.11 simulation software based on international standards of Illuminating Engineering Society of North America (IESNA).The conventional bulbs on the shop floor has been replaced with LED lights as per software design. After hardware installation it is revealed that by adopting this lighting scheme there is 45% of energy savings and user satisfaction with financial savings of Rs. 912,711 per year having 3.78 years pay back period that justifies use of LEDs as per proposed lightning design for general lighting applications.

Keywords: Compact fluorescent light (CFL), Light emitting diode (LED), Incandescent Lamps (IL), Conventional bulbs, Foot candle (fc)

1. Introduction

Energy is one of the fundamental requirements for the human development and economic growth. In Pakistan severe electricity shortages has occurred due to demand supply gap which led to blackouts and it has severely damaged the industrial setup as major chunk of electricity is consumed by industry. One way to cope with the same is to adopt the passive building design and conserve energy in buildings by smart technologies.

Buildings consume 20 to 50 % of global energy by artificial lighting and this figure is rising [1]. In industries 4-5% of total industrial electrical energy is consumed for lighting [2]. Energy saving while maintaining the required lighting level is a challenging task in designing lighting schemes for buildings. Lighting is a large growing source of energy demand and Green House Gas (GHG) emission [3]. For artificial lighting most common sources are the Incandescent Lamps (IL) and compact fluorescent lamps (CFL). IL is inefficient, converts 90% of electrical energy into heat [4] and short bulb life. CFLs are more efficient than incandescent bulbs in terms of energy saving [5] long life [6] but it contains hazardous material mercury [7], slow response time and recycling issues. This leads to a unique lighting technology called Light Emitting Diodes (LED).

LEDs lights can potentially overcome many problems, low power consumption, fast switching [8] minimum cost incurred on maintenance [9], high output (lumen/ Watt), long-lasting, high tolerance to humidity [10, 11] no radiations, no recycling issues like CFLs and no premature lamp failure like incandescent and eco friendly [12,13]. Therefore, traditional light bulbs are replaced with LED for energy saving, financial effects [14] better performance [15], high forbearance to dampness**,** cool operation [16, 17] extended life and are highly efficient as shown in Table 1 [18].

Table 1. Comparison of LED with Traditional light sources [18].

Lights Type	Output (Lumen/watt)	Estimated Life Span(Years)	Maintenance cycles
LED	20-120	34	Nil
HPS	80-100	2	17
CFL	50-100	1	34
Incandescent	20	6 months	68

The luminous level for work place is defined by Lux, lumen /watts and foot candle. Table 2 shows the recommended illumination level for indoor lighting design for different environments [19, 20].

* Corresponding author : dr.aamirhanif@wecuw.edu.pk

Table 2. Recommended Illumination level [19, 20].

Work Area	Foot candles (fc)
Class rooms /Offices	30 - 50
Rough bench work(Industrial)	30
Medium contrast	50-100
Low contrast and very small Task	100-200
Welding- precision	300-1000

Lights are chosen having color rendering index greater than 80 to render all colors accurately [21]. Color rendering index of various lights is shown in Table 3 [22].

Table 3. Evaluation of CRI of diverse Light Sources [22].

Property	Incandescent	Fluorescent	LED
CRI	100	62 – 82	92

LEDs are widely used for general lighting [23] and in automobile industry [24].

Section 1 of the paper explains the different lighting technologies and their comparison with LED lights. Section 2 describes the methodology of the research opted for replacement of conventional lights by LEDs for an industrial setup as per proposed lightning design to achieve energy and cast saving. In section 3 a case study is presented for an industrial setup through installation of hardware as per developed lightning design. Results are discussed in section 4 of the paper. Paper is concluded in section 5.

2. Methodology of Research.

Figure1shows the flow chart of proposed energy conservation solution strategy.

In proposed strategy first of all site for the project is selected and its indoor area is measured. By using Lux meter the existing illumination level of conventional bulbs is measured. Obtained illumination level is matched with international standards of Illuminating Engineering Society of North America (IESNA). For the area/site under consideration a new lighting scheme is developed by using measurements of selected area and adding the standards for that specific environment to simulation software DIALux 4.11. As per design, the hardware is installed and illumination level is measured for LED lights by using Lux meter and results are compared with that of conventional lights prior to installation of LED lights.

In order to check how viable the new lighting scheme is, energy savings and cost savings calculations are made. Finally payback period has been calculated to justify the implementation of new lighting scheme.

3. Case Study

The case study is of an industrial workshop which is a machine shop operated 23 hours in a day in 3 shifts. The area of the shop is 186 ft x 98ft and height of shop is 20ft. The shop is installed with 236 machines including 51 presses. The height of machines in shop varies from 4ft to 14ft. Electrical supply and compressed air connections are provided to the machines by overhead bus bars and compressed air pipe lines respectively. Total electrical connected load of the shop is 2.4MW including 20.015 KW lighting load. The shop was installed with 173 conventional lights suspended 5ft below from roof. The illumination level on different test points with conventional bulbs (Mercury bulbs, Tube lights and Energy savers) is measured by Lux meter and recorded as Figure 2.

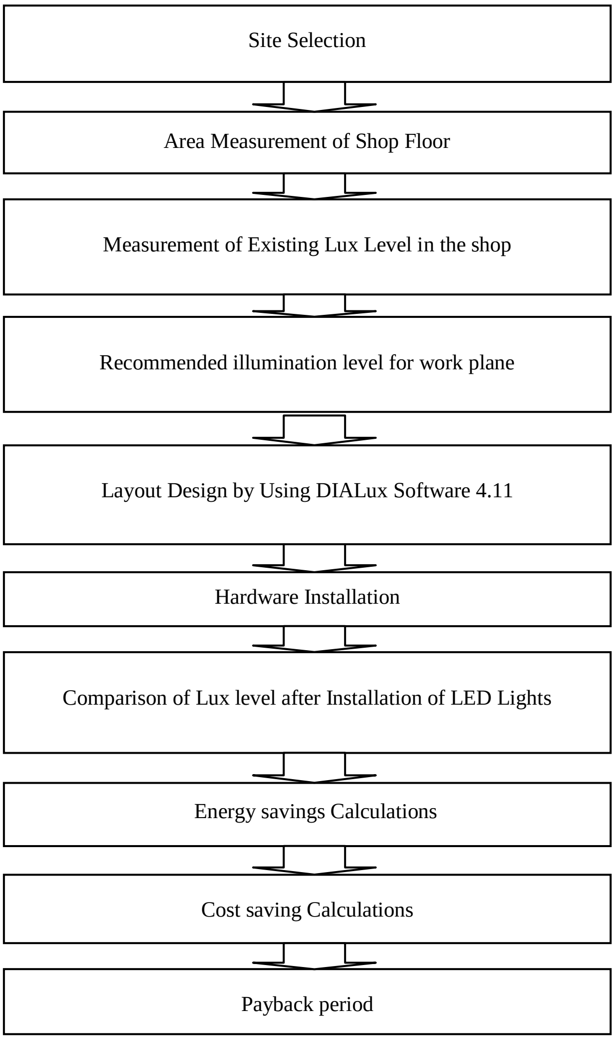


Figure 1. Flow chart for an energy conservation scheme.

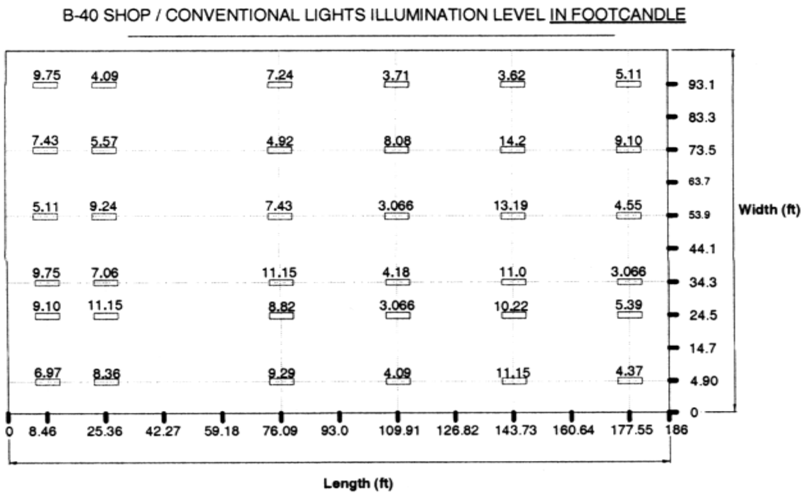


Figure 2. B-40 Shop / Conventional Bulbs Illumination Level in Foot Candle.

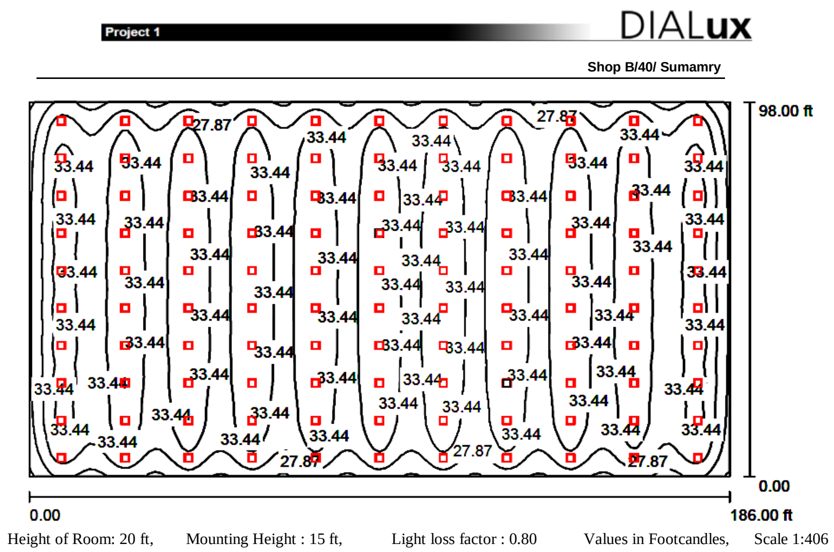


Figure 3. Lay out design of B-40 shop by using DIALux 4.11.

Figure 2 shows poor illumination level. The recommended illumination level for this working environment is 30 foot candles as per Illumination Engineering society of North America (IESNA) [19, 20]. To achieve the target illumination level DIALux 4.11 simulation software is used to design a new lighting scheme for the industrial work shop which shows number of lamps required along with layout design on luminaries. Number of lamps can also be calculated manually by using Lumen Method.

The equation is appended below;

$$N = \frac{E \times A}{F \times UF \times MF}$$

Where

N= Numbers of lamps required

E= Average illumination required in Lux

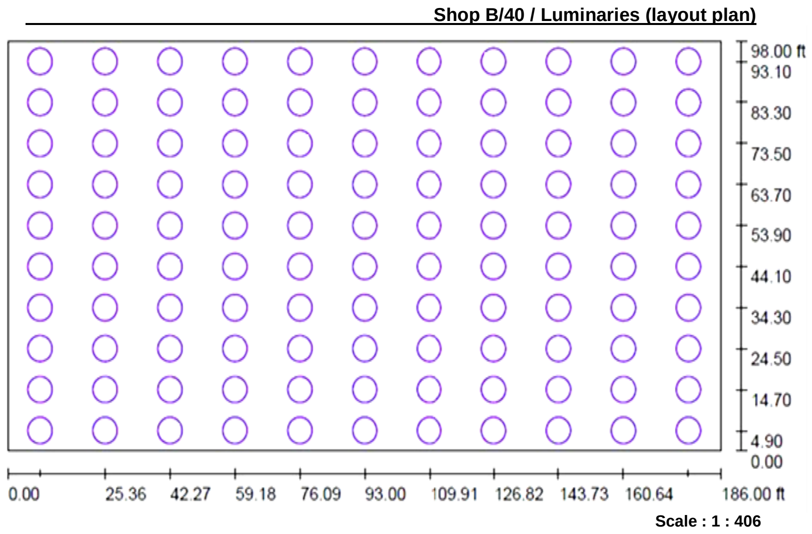
A= Area of working plane (m^2)

F= Light output from Lamp (Lumens)

UF= Utilization factor (Light distribution from Lamp)

MF= Maintenance factor (Reduction in light output because of deterioration and dirt.)

Figure 3 shows the layout design for the shop under consideration and showing Lux level on different points in foot candles. The designed layout consists of 110 LED lights each of 100 watts. The design shows uniform lighting scheme and Figure 4 shows the detailed luminary layout for the installation of lights and distance between them horizontally and vertically along with details of work plane.



Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	110	TRILUX Belviso C1 625 CDP LED3900nw 01 ET Belviso··· (Type 1)* (1.000)	6391	6400	100.0
*Modified Technical Specifications			Total: 702992	Total: 704000	11000.0

Specific connected load: 0.60 W/sq ft = 0.18 W/sq ft/10 fc (Ground area: 18228.43 sq ft)

Figure 4. Luminaries layout plan for B-40 shop

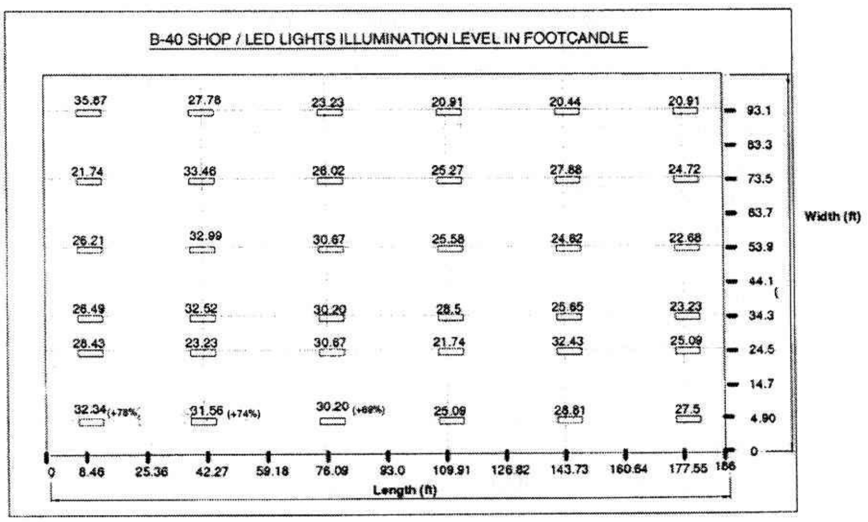


Figure 5. B-40 shop / LED lights illumination level in foot candle.

The average, maximum and minimum illumination level is also shown in foot candles by simulation results as written below :

Surface	Eav [fc]	Emin [fc]	Emax [fc]
Work plane	33	16	40

3.1. Hardware Installation

The lighting load of the workshop was 20.015KW which has been replaced with 11.00KW new lighting load LED lights. The lights has been installed at the height of 15ft from ground and the illumination level is recorded by Lux meter in foot candle on work plane (2.43ft) on test points same as in Figure 5 to compare the results. The result shows that the lighting level in B-40/shop has very much improved after installation of LED lights.

Table 5. Conventional Bulbs vs. LED Lights.

Types of Lights		Quantity	Total Watts	Total KW	Installation Cost (PKR)	Units Consumed/ Day
Conventional Bulbs	Mercury Lamps	53 No (275w/Each)	14575	20.015	265,000	20.015 x 23 460.345KWH
	Tube Lights	40 No (100 w/Each)	4000		128,000	
	Energy Savers	80 No (18 w/Each)	1440		120,00	
LED Lights	LEDs	110 No (100 w/Each)	11000	11	385,0000	11 x 23 = 253 KWH

The recorded light output from LED light sources varies due to height of machines (4ft -14ft), overhead bus bars and compressed air pipe lines.

4. Results and Discussions

Before installation of LED lights the shop was installed with 173 traditional bulbs with lighting load of 20.015 KW. To achieve the recommended illumination level and energy savings through an efficient lighting design and use of LEDs; these conventional bulbs were replaced with LED lights with lighting load of 11KW. The wattage of luminaries and installation cost incurred on traditional and LED bulbs is shown in Table 5.

4.1. Percentage Energy Savings

20.015KW lighting load of conventional bulbs has been replaced by 11KW lighting load of LED lights saving 45% of electrical energy.

4.2. Financial Effects

Detail of financial effects is given with payback period calculations.

Case (i): Light Usage Profile (Full Load).

The workshop is being operated 23hrs per day and rate of electricity per unit is taken as PKR 12.06.

Annual Cost of Electricity Consumed by conventional Bulbs = 460.345 x 12.06 x 365.
= 2,026,392.66 PKR

Annual Cost of Electricity Consumed by LED Lights
= 253 x 12.06 x 365= 1,113,680.70 PKR

X = Annual Cost Saving /Year = 912,711 PKR

Initial Investment

on Conventional Bulbs = 405,000 PKR

on LED Lights = 3,850,000 PKR

Y= Difference of Installation Cost = 3,445,000 PKR

Simple Pay Back Period (SPBP)

SPBP =Y/X =3.78 Years

Case (ii): Light Usage Profile (Average Load of Shop)

The shop is being operated round the clock. In night shift the light consumption is 41% less than full load of the shop.

Night Shift Load by Conventional Bulbs = 11.825 KWH/ day

Average load of the shop = 15.92KWH/ day

Electricity consumption in KWH by
conventional bulbs =15.92 x 23 = 366.16 KWH / Day

As the night shift load of shop is 41% less than the full load in case of conventional bulbs. Before installation of LED bulbs the load of night shift of LED can be taken as 41% less than full load by LED lights. Therefore, night shift load by LED light is 4.51KWH less which may change after installation of LED bulbs.

Night Shift Load by LED Bulbs = 6.49 KWH

Average Load of the shop = 8.745 KWH

Electricity consumption by
Average load/day = 8.745 x 23 = 201.35 KWH/day

Financial effects

Units consumed by conventional
bulbs/day= 366.16 Units

Cost of units consumed / year = 366.16 x 12.06 x 365

= 1,611,799.704 PKR

Units consumed by LED bulbs / day = 201.35 Units

Cost of units consumed by
LED lights / year = 201.35 x12.06 x 365

= 886,322.57 PKR

X = Annual Cost Saving / year = 725,477.135 PKR

Initial Investment

Initial Investment on Conventional Bulbs = 405, 000 PKR

Initial Investment on LED Lights = 3,850,000 PKR

Y= Difference of Installation Cost = 3,445,000 PKR

Simple Pay Back Period (SPBP)

SPBP =Y/X

SPBP = 4.8 Years

5. Conclusion

LEDs are the future technology highly promoted for their low energy consumption, long life, efficiency, reliability, and ease of use in improved and innovative designs and having potential to save energy. Case study for an industrial set up using LEDs is carried out that shows 45% of energy saving and financial savings of 912,711 PKR per year with payback period of 3.78 years. The results show that LEDs are best recommended for general lighting application and white LEDs are replacing incandescent and compact fluorescent lamps. The major disadvantage associated with LED lights is that the installation cost of these devices is still at higher side, however this issue can be resolved by more energy saving and reducing payback period.

References

[1] P. Hawken, A. Lovins, and L. Hunter Lovins, Natural Capitalism. Back Bay Press, Time Warner Book Group (2000).

[2] A. Dhingra and T. Singh, Int. J. of Energy **3** (2009) 1.

[3] D.M. Warana and K.K.J Kailas, IEEE Tencon **38** (2013) 3563

[4] Incandescent Lamps, Public. Number TP-110, General Electric Company, Nela Park, Cleveland, OH (1964) p. 3.

[5] S. Ahmed, Industry Applications Conference, Kowloon, Hong Kong **4** (2005) pp. 2965-2971.

[6] http://en.wikipedia.org/wiki/Compact_fluorescent_lamp The National Energy Foundation - Low Energy Lighting - How to Save with CFLs. Available online dated.01 Feburary (2012).

[7] J.J. Horng, Y.K. Su, S.J. Chang, W.S. Chen and S.C. Shei, IEEE Transa. on Device and Materials Reliability **7** (2007) 340.

[8] Yong –Nong Chang, Hung-Liang Cheng and Chih- Ming Kuo, Int. J. of Photoenergy **27** (2013) 471384

[9] C. Y. Wu, T. F. Wu, J. R. Tsai, Y. M. Chen and C. C. Chen, IEEE Trans. on Industrial Electronics **55** (2008) 3791.

[10] Huang-Jen Chiu, Yu-Kang Lo, Jun-Ting Chen, Shih-Jen Cheng, Chung-Yi Lin and Shann-Chyi Mou, IEEE Trans. on Industrial Electronics **57** (2010) 735.

[11] P. Mashkov, T. Pencheve and B. Gyoch, LED Optimizing for Long term Lumen Maintenance, IEEE. 33rd Int. Spring Seminar on Electronic Technology (2010).

[12] S.K. Kim, H.S. Han, Y. J.Woo and G. H. Cho, IEEE Transa. Indus. Electro. **53** (2006) 707

[13] M.R. Krames, H. Amano, J.J. Brown and P.L. Heremans, IEEE J. Sel. Topics Quantum Electron, **8** (2002) 185.

[14] Y.K. Cheng and K.W.E. Cheng, 2nd International Conference on Power Electronics Systems and Applications, Hong Kong, 12-14 November (2006) pp. 173-177.

[15] K.H. Loo, Wai-Keung Lun, Siew-Chong Tan, Y.M. Lai and Chi K. Tse, IEEE Trans. on Power Electronics **24** (2009) 2967.

[16] S. Muthu, F. J. P. Schuurmans and M.D. Pashley, IEEE J. Selected Topics in Quantum Electronics **8** (2002) 333.

[17] G. Pang, T. Kwan, H. Liu and C.-H. Chan, IEEE Ind. Appl. Mag. **8** (2002) 21.

[18] Comparison Chart LED Lights vs. Incandescent Light Bulbs vs. CFLs, Available on-line at http://www.designrecycleinc. com/led% 20comp % 20chart.ht dated 29 December (2011).

[19] Illuminating Engineering Society of North America (IESNA), Lighting Handbook 9th Edition (2000).

[20] Industrial lighting ANSI/IESNA RP-7- 01, Recommended Practice for Industrial Facilities (1991).

[21] B Soni, MISTE J. of Theor. Appl. Info. Tech. **4** (2008) 1083

[22] G. Gereffi, K. Dubay and M. Lowe, Comparison of Current Lighting Technology, Krieger (2008).

[23] S.Moon, G.B.Koo and G.W.Moon. IEEE Trans. Power Electronics **28** (2013) 4051.

[24] I.Takai , S. Ito, K.Y. Tomi, K.Kagawa, M.Andoh and S. Kawahito, IEEE Photonics J. **5** (2013) 6801418.