

## Energy Efficient Lighting

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### Introduction

Most often inefficient use of electrical lighting in home and factories causes wastage and losses. This wastage can be measured and reduced by taking appropriate action like energy auditing. Energy auditing is done to identify the possible areas of wastage like inefficient and excess use of lights. By taking appropriate measures energy can be used efficiently in lighting.

### Lighting

Lighting consumes about 30% of total electrical energy used in Bangladesh. The amount of light needed varies with the type of work performed. Garment or electronics industries need maximum light whereas other types of factories like textile mills just need less lumen per square foot. Various types of light are available with different lumens and colour. In this country incandescent and fluorescent lights are mostly used. Fluorescent lights are extensively used in factories specially garment industries. Energy efficient lights are available in the market for sometimes but the cost is high. A 1993 Philips Bangladesh study estimates those General Lighting Services (GLS) lamps with approximately 6.5 million light point [1] and 1.0 million Fluorescent lamps (FL) with approximate 1.0 million light points. Worth mentioning among other type of lamps are Low Pressure Sodium Lamps (LPSL) with approximately 100,000 and 20,000 light points. Remaining types, Compact Fluorescent Lamps (CFL), High Pressure Metal Halides lamps (PMHL), Halogen Lamps (HL), etc. are insignificant in numbers. A 2003 estimate suggests that there are about 9.6 million GSL and about 1.5 million FL are in use [2]. Characteristic [3] of these lamps with lumen are shown in Table 1. In year 2002-03 estimated 41% and 5% of total electricity consumed by commercial and domestic consumers; and industrial consumers respectively were used for lighting purpose. Recent research has come up with energy efficient LED, which will consume 80% less electricity.

The main problem of this sector is the quality control of lighting products. Very low quality ballast, CFL etc. not only cause problem to the electricity supply system but also causes foreign currency loss.

Industries where lumen requirement is very high should use Energy Efficient Lights (EEL). Although the initial cost is very high, but during its lifetime savings are over 50%. Electronic ballast for fluorescent light is double the price of conventional magnetic ballast but the energy consumption is about 25%. Conventional magnetic ballast takes about 8 to 10 watts whereas electronic ballast takes about 2 watt per 40 W tube. Payback period is about 2 years.

Table 1 Light Source Characteristics

Type	Lumen Per watt	Life X 1000 Hours	Relative efficiency based on HPS	Start-up-time (minute)	Lumen maintenance	Colour Rendition	Operating Cost
Incandescent	15-25	0.75-12	19%	Immediate	Fair to Excellent	Excellent	High
Florescent	55-85	7.5-24	65%	Immediate	Fair to Excellent	Good to Excellent	Average
Compact Fluorescent Light(CFL)	45-60	10	46%	Immediate	Good	Good	Low
LED Lights	70-120	50-100	92%	Immediate	Very Good	Good	Very Low
Mercury Vapor	50-60	16-24	46%	2-7	Very Good	Poor to Excellent	Average
Metal Halide	80-100	1.5-15	77%	2-5	Good	Very Good	Below Average
High Pressure Sodium (HPS)	75-130	20-24	100%	3-4	Excellent	Good	Low

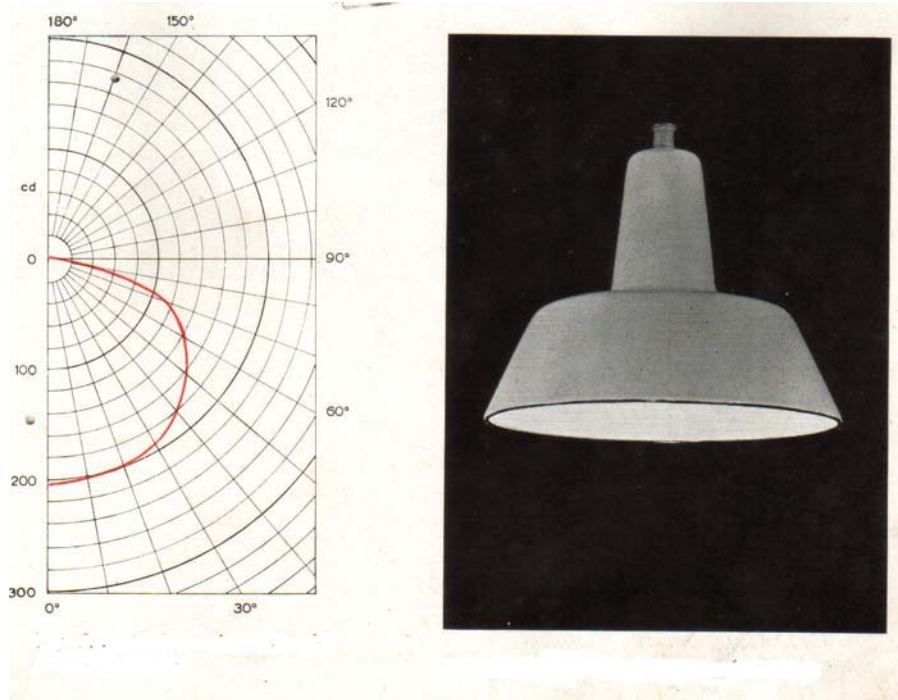
### Definitions

Various terms and definitions are used to quantify light, light source, etc. They are luminous flux, luminous intensity, illumination, luminance, etc. These definitions are explained in Appendix -A.

The luminous flux from a light source is never emitted in a completely uniform manner. The characteristic of different light source and fittings are shown in Fig. 1.

### Different Types of Lights

There are different types of lights bulbs available in the market. These light bulbs are used for different kind of applications such as home lighting, industrial, sports, decoration, architectural lighting, etc. From January 1, 2001 all lamps for domestic use in developed countries must carry an energy level that indicates energy efficiency class on a scale of A (very efficient) to G (inefficient).



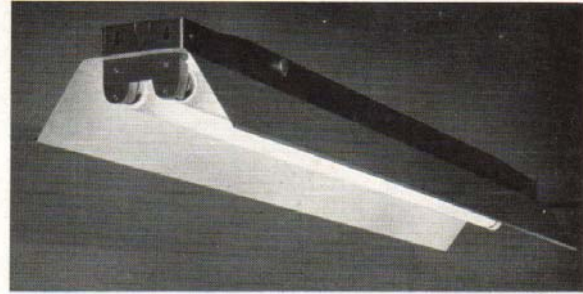
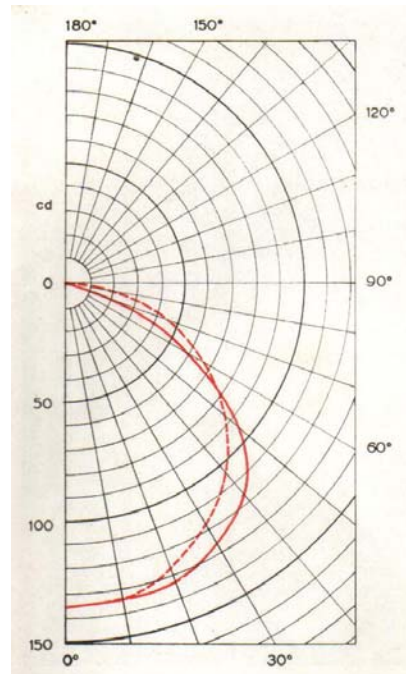


Fig. 1 Luminous intensity diagram

### ***Incandescent lights***

The most common lights are the incandescent lights usually called “Light Bulb”. The incandescent and quartz-halogen lights develop their light by passing current through a thin high resistance tungsten wire which gets hot and radiates light. Along with the visible light comes a great deal of heat, so the lights are lowest in efficiency. Only 5% of the input energy is converted to visible light. The tungsten filament gradually evaporates and weakens, and the metal that evaporates gradually coats the inside of the bulb, reducing brightness. Incandescent lights are available in a wide range from 5, 25, 40, 60, 100, 200, 250 Watts and higher capacity and are also available for 12 volt DC operation. This is the cheapest and most commonly used bulb in this country.

### ***Fluorescent lights***

In Fluorescent lamps, mercury vapor is excited inside a tube by alternating current, and light is emitted by the gas. The light strikes the inner coating of the tube which is some type of fluorescent material, producing a soft glow. The light produced falls well within the visible range, so the efficiency is good.

Traditionally fluorescent bulbs have long cylinders ranging from a few watts to 40 watts. New “parallel lengths” or PL lamps are now available that are much more compact. The PL lamps fold back the long cylinder to make a compact “H” shape, double “H” or quad PL lamps are also available. PL type lamps are available

5,7,9,13,18 or 24 and 36 watts. To operate from DC power, a ballast is needed to produce high frequency AC current.

Fluorescent lamps are extensively used in industries, especially garment industries. There are about 4100 garment (2004-05) industries under BGMEA. Thousands of FL is used in these factories. There are two types of FL are available in the market 40 W and 36 W with the same lumen output. There is a saving of 4 W per tube. Moreover, good quality electronic ballast with 36 W lamps could save power.

### ***High Intensity Discharge (HID) Lamps:***

The HID lights are Mercury vapor, metal halide, low pressure and high pressure sodium lights. These lamps are ideal for outdoor applications like security lighting where lamps will be operated for extended periods of time.

The mercury vapor lamp produces a harsh bluish-white light and is the least efficient of HID lamps. They have a low initial cost, but higher operating costs than other HID choices.

Metal halide lamps have good colour rendering capabilities and are widely used for sporting event lighting.

The low pressure sodium lamps produce a harsh yellow-gold colour and are suitable only for general outdoor lighting. They are most efficient of light sources, but the harshness of light makes their applications limited.

High pressure sodium lamps are the most efficient of the white light sources. They produce a soft amber colour and are used for street lighting and other exterior lighting applications.

### ***Compact Fluorescent Lights***

Compact Fluorescent Light (CFL) is an energy efficient light. The main benefits of CFLs are 80% savings in electricity costs compared with incandescent lamps of same brightness. And up to 13 times the life of incandescent lamps. But the main problem is price. It is about 15 times costlier than incandescent lamp in local market. The price can be reduced if government duty is reduced. Renowned light manufacturers like Philips, GEC, OSRAM have developed energy efficient starters like Conventional Control Gear (CCG) and Electronic Control Gear (ECG), which not only save energy but also bring longer lamp life. Recently about 100,000 pieces per months are sold which is 1.2 million pieces per year.

### ***LED lights***

Recent development of Light Emitting Diode (LED) lights (Fig. 2) may revolutionize the lighting industries. These lights can be used until now to some specialized use.

A light-emitting-diode (LED) is a semiconductor diode [4] that emits light when an electric current is applied in the forward direction of the device, as in the simple LED circuit. The effect is a form of electroluminescence where incoherent and narrow-spectrum light is emitted from the p-n junction. LED lights operate on DC voltage. AC LED lights are still in experimental stage.

There are two ways of producing high intensity white-light using LEDs. One is to use individual LEDs that emit three primary colors– red, green, and blue, and then mix all the colors to produce white light. The other is to use a phosphor material to convert monochromatic light from a blue or UV LED to broad-spectrum white light, much in the same way a fluorescent light bulb works.

Wal-Mart, a retailer giant supermarket chain with 5,200 stores world wide has come up with new idea of energy saving in lighting. [5]. One of the biggest items on its energy bill is lighting. Instead of going with the cheapest bulbs, the company is experimenting with costlier LED strips for refrigeration units that last longer and use less energy. In future it might replace the GLS lamps.

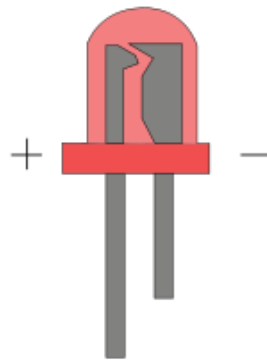


Fig. 2 LED light

### ***Smart light***

By using occupancy sensor lights can be switched on and off. These smart lights are usually used in spaces, which are not all the time used/occupied, like corridor, elevators, etc.

### **Illumination Society**

There is an illumination society called Illumination Society of Bangladesh (ISB), which works for disseminating the knowledge of illumination engineering to bulb manufacturer, light fixture industries and lighting engineers. ISB is a member of World Illumination Society (WES). WES has 8 divisions covering all the aspect of

illumination engineering from Road Lighting, Industrial Lighting, Vision, Standards, etc.

## Case Studies

### *Use of energy efficient lights*

Industries where lumen requirement is very high should use Energy Efficient Lights (EEL). Although the initial cost is very high, but during its lifetime savings is over 50%. In domestic sector the initial cost may be high when compared to middle class people's income. So, there must be some sort of incentive. If they do not levy taxes on EEL, then the price will be within the reach of many people.

Energy Research Group of UTM conducted a research project on electrical energy consumption pattern of residential area. In this research [6] the load pattern and energy consumption of one housing area namely Taman Sri Temapoh in Negri Sembilan state was studied for about five months. One model house in the area was fitted with energy monitoring equipment, i.e. Energy Analyzer. Some lights of the model house were replaced by energy efficient lights, keeping the lumen requirement same. The model house was a 3-bedroom single storied terrace house fitted with 5 incandescent lights of 60W each and 4 fluorescent lights of 40W each. The incandescent lights were replaced by three 18W and two 13W CFLs. The Energy Analyzer recorded the voltage, current, power and power factor for every 30 minutes and a print out of data was taken every 24 hours for about five months. The load curve is depicted in Fig 3. The economic benefit is shown in Table 2.

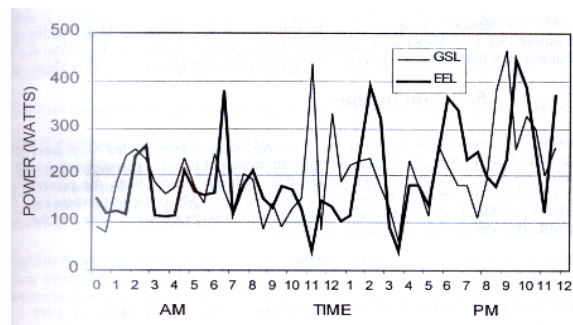


Fig. 3 Daily load curve of the model house

From Table 2 it can be calculated that the pay back period for replacing GLS by EEL in the model house is about 10 months. From the load curve (Fig. 4.3) it can be seen that by using CFLs, the overall energy savings is about 18%.

In Bangladesh if 10% of all GLS [7] (which consumes about 1080 MW) could be changed to EEL (consumes 60% less electricity), then load reduction is over 42.12MW ( $1080 \times 10^6 \times 0.1 \times 0.65 \times 0.6 = 42.12$  MW, Demand Factor=0.65, 2004-05 data used).

Table 2 Cost Comparison of EEL and GLS lamps in the model house

	Fluorescent light	Incandescent light	Compact Fluorescent Light
Nos. x Watt	4×40	5×60	3×18, 2×13
Life time, hours	4000	1000	8000
Light output, lux	100	60	75
Usage, hours/days	17	11	7,4
Initial cost, RM	4×5=20	5×2=10	5×34=170
Energy Consumption per day, kWh	2.72	3.3	0.482
Energy Consumption per year, kWh	993	1205	176
Cost of Energy, RM (@RM 0.2 per unit)	199	241	35
Total Cost per year, RM	219	251	205

### **Retrofits**

The existing lighting arrangement in a system can be retrofitted with electronic ballast, high output fluorescent tubes and quality reflector to improve efficiency. Such a system is reported [8] here. The overall pre-retrofit lighting power density was improved from 2.3 W/ft<sup>2</sup> to 1.49 W/ft<sup>2</sup>. The payback period was calculated as 15 months. Table 3 shows the density and illumination level before and after retrofits.

Table 3: Lighting Load Before and After Retrofit

#### A. Before retrofit condition

Tubes per fitting	Watts per tube	Ballast loss	Number of fittings	Wattage
3	36	30	136	18768
3	58	51	105	23625
2	36	20	105	9752
2	58	34	108	16200
			Total	68345

Total lighting load = 68.345 kW

#### B. After retrofit condition

Tubes per fitting	Watts per tube	Ballast loss	Number of fittings	Wattage
1	32	4	242	8712

1	52	6	213	12354
			Total	21066

Total lighting load = 21.066 kW

Thus the estimated load reduction due light fitting on Level = 47.28 kW

### ***Natural light***

An alternative source of light could be natural light. Some industries need large floor space with medium intensity of lumen per square. Natural light could be integrated in the rchitectural design of such factory building. Fig 4 shows a KLIA, Malaysia. Natural is integrated in airport lighting in Tribhuban International Airport, Kathmandu, Nepal and Kuala Lumpur International Airport (KLIA), Malaysia.



Fig. 4 Use of natural light in KLIA

### **Conclusion**

This lecture discussed the various methods of energy saving measures in lighting sector for home and industries. Some of the measures may be cost effective and suitable. In depth cost analysis and socio-economic condition should be studied before they are implemented.

### **References**

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- [2] B.D. Rahmatullah, Draft Report on CFL, Power Cell, 16 October 2003.
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- [4] Wikipedia, October 2008
- [5] Time Magazine, April 3, 2006

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## Appendix-A

Various terms and definitions related to illumination levels:

### Luminous flux:

- the total quantity of light emitted per second
- unit: lumen (lm), that is 1/680 W, emitted at a wavelength of 555m $\mu$ .
- Symbol:  $\Phi$  (phi)

### Luminous intensity:

- The luminous flux emitted per unit of solid angle in a given direction.
- Unit: candela (cd) = 1/ 60 of the luminous intensity of the black body at the temperature of solidification of platinum (2046°K).
- Symbol:  $I$ .

### Illumination:

- the incident luminous flux per nit of area.
- Unit: lux (lx); 1 lux= 1 lumen / m<sup>2</sup>
- Symbol:  $E$ .

### Luminance:

- the luminous intensity per cm<sup>2</sup> or m<sup>2</sup> of the apparent area of a source of light or of an illuminated area.
- Unit: cd / cm<sup>2</sup> or cd / m<sup>2</sup>.
- Symbol:  $L$ .

### Average illumination:

The average illumination on an area is equal to the total luminous flux, which falls on the area, divided by the area,

$$E_{av} = \Phi / S$$

In which  $E_{av}$  = the average illumination in lux.

$\Phi$  = the luminous flux in lumens.

$S$  = the area in m<sup>2</sup>

Or

$$\text{Lux} = \text{lumens} / \text{m}^2$$

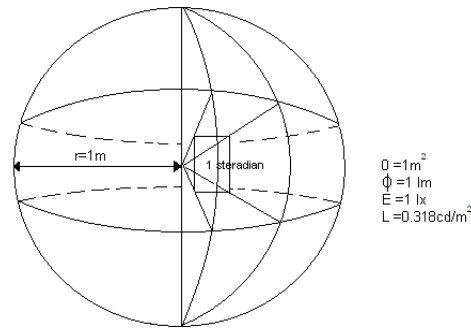


Fig. A1 Relationship between the principal units of lighting engineering

### Illumination at a point:

The illumination at a point is equal to the luminous intensity divided by the square of the distance of the source of the light to the point in question.

$$E_p = I / r^2$$

in which  $E_p$  = illumination at the point  $p$  in lux

$I$  = the luminous intensity in candela

$r$  = distance from the light source to the area in m.

Or

$$\text{Lux}_p = \text{candela} / (\text{m})^2$$

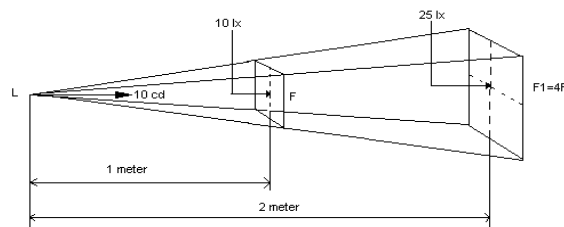


Fig. A2 The square law

### Luminance of a light source:

The luminance of a light source or a reflecting surface is equal to the light intensity divided by the apparent surface.

$$L = I / S_s$$

In which  $L$  = luminance in  $\text{cd} / \text{cm}^2$   
 $I$  = luminous intensity in candela  
 $S_s$  = apparent area in  $\text{cm}^2$

### Luminance of a diffusely reflecting area:

The luminance of a diffusely reflecting area is equal to the product of illumination and the reflection factor, divided by the factor  $\pi = 3.14$ .

Or

$$L = E \times r_v / \pi$$

#### Lux levels for various purposes:

Summer, midday, in an open field, cloudless sky	100,000	Lux	
Winter, midday – open field	10,000	Lux	
Summer, midday, under a balcony	2,000 – 5,000	Lux	
Summer, midday, behind a window	1,000 – 3,000	Lux	
Sunrise and sunset	500	Lux	
Full moon and bright sky	0.25	Lux	
Living – room table with good lighting	500	Lux	
Office with good lighting	800	Lux	
Sun	1,650,000	LUX <sub>P</sub>	
Moon	2,500	LUX <sub>P</sub>	
Filament of an incandescent lamp	7,000,000	LUX <sub>P</sub>	
“Argenta” lamp	200,000	LUX <sub>P</sub>	
SO sodium lamp	190,000	LUX <sub>P</sub>	
“TL” fluorescent lamp (lateral direction)	8,000	LUX <sub>P</sub>	
“TL” fluorescent lamp (longitudinal direction)	5,000	LUX <sub>P</sub>	
White paper	1,000,000	LUX <sub>P</sub>	Reflection factor 80%
Grey paper	500,000	LUX <sub>P</sub>	Reflection factor 40%
Black paper	50,000	LUX <sub>P</sub>	Reflection factor 4%

#### Various types of lamps:

#### *[SHORT SURVEY OF THE PRINCIPAL TYPES OF PHILIPS INCANDESCENT LAMPS]*

#### *Lamps for general lighting:*

Vacuum or gas-filled lamps; either internally frosted or opalised. Top reflector lamps; frosted and half-mirrored inside. Used with the specially designed fittings, they give

diffuse illumination with pronounced direction. Night lamps and plug-in lamps, low power; used as night lights in bedrooms and in hospitals.

*Lamps for festive lighting:*

Spherical lamps, candle lamps and chandelier lamps. Frosted or opalised finish, also available in flame color. Philinea opal tube-shaped lamps are among other things, used for illuminating mirrors. Colorenta lamps. Colrentina lamps for chandeliers and wall ornaments.

*Internally mirrored spot and flood lamps:*

150 W pressed glass lamps are internally mirrored and radiate a beam just as the “Comptalux” and “Attralux” lamps do, but with a noticeably greater light intensity and a more favorable luminous efficiency. The “floodlight” type has a relatively broad beam while the “spotlight” type has a narrow beam.

100 W and 150 W “Comptalux” lamps are used for shop and window display illumination. They give a broad beam, which provides strong local light accent.

100 W and 150 W “Attralux) lamps (also for 24 V – 150 W) give a narrow beam with great light intensity (up to 20,000 cd); and are also used for shop and display lighting.

“Altrilux” lamps give a very narrow beam and are used for high bay lighting as in factory halls; are also used for floodlighting and for sports grounds.

*Reinforced construction lamps:*

These are intended for use where vibrations and shock are more than normal. Welding lamps are of reinforced construction, and the bulb is specially prepared to resist damage from metal particles. Rough service lamps are intended for those places where particularly violent vibrations occur.

*Signal lamps:*

Signal lamps and neon signal lamps use little energy: they are intended for signal installations and switchboards.

*Colored lamps:*

Suitable among other things for festive illumination. They are supplied with differently colored bulbs.

*Low voltage lamps:*

These are used for illuminating ships, for independent domestic lighting, emergency lighting and for inspection lamps.

*Special lamps for various uses:*

Sewing machine lamps, oven lamps, devotional lamps, showcase lamps, and Christmas tree illuminating sets are only a few selected at random from a very extensive series of special lamps.

*Thermal radiators, heating lamps and drying lamps:*

Thermal radiators are satin-coated or ruby-glass enameled and internally mirrored. They are used for chicken and pig rearing.

Heating lamps are internally mirrored, hard glass bulbs are used for the heating of bathrooms, shower cubicles and, in general, rooms, which are only in use for, short periods at a time. Drying lamps with hard glass bulbs are used in industry for drying processes, such as, for example, stove-enameling.

Illumination values**For home use:**

Type of work	Recommended values of illumination in condition of operation (lux)
<b>Living rooms</b>	
General.....	100-50
Locally (reading, writing, needlework, etc).....	1000-500
<b>Kitchens</b>	
General.....	250-125
Locally (stove, dresser, table).....	500-250
<b>Bedrooms</b>	
General.....	100-50
Locally (mirrors, dressing-tables, bed-lighting).....	500-250
<b>Hallways, staircases, lofts, garages</b>	
General.....	100-50
Locally (work-benches, hobby tables).....	500-250

**For industrial use:**

Type of work	Recommended values of
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	illumination in condition of operation (lux)
<b>Ceramic industry</b> Grinding, straining and compressing, drying... ..... Shaping, finishing and cleaning..... ..... Coloring and glazing (coarse)..... Coloring and glazing (delicate).....	200-100 300-150 800-400 1500-750
<b>Chemical industry</b> Hand-operated furnaces, stationary dryers, boiler and crystallization tanks Mechanical furnaces, steam boilers and distilling tanks, mechanical dryers and crystallization tanks, evaporation vessels, filtering, bleaching..... Thickening-boilers, extraction, filtering and nitration equipment, electrolysis.....	300-150  300-150  300-150
<b>Garment industry</b> Inspection of light fabrics..... Inspection of dark fabrics..... Cutting and pressing of light fabrics..... Cutting and pressing of dark fabrics..... Sewing and trimming of light fabrics..... Sewing and trimming of dark fabrics.....	3,000-1,500 5,000-2,500 1,000-500 2,000-1,000 1,500-750 3,000-1,500
<b>Leather industry</b> Cleaning, tanning, stretching, dying..... Splitting, fleshing and readying..... Finishing and inspection..... Pressing and lusting..... Inspection, sorting, cutting and	300-150 400-200 800-400 1,500-750 2,000-1,000

sewing.....	
<b>Textile industry</b>	
Cotton bale breaking, mixing, sorting.....	200-100
Cotton carding, drawing, sizing, bobbin winding, spool	400-200 800-400
winding, spinning.....	800-400
Cotton	3,000-1,500
weaving.....	200-100
Inspection stationary pieces.....	400-200
Inspection fast moving pieces.....	1,500-750 800-400
Silk and synthetic fiber degumming, dyeing, drying	200-100 200-100
Silk and synthetic fiber bobbin winding, spool winding,	800-400 400-200
twisting, warping, spinning.....	400-200
Silk and synthetic fiber light colored yarns.....	800-400 800-400
Silk and synthetic fiber dark colored yarns.....	1,500-750
Silk and synthetic fiber weaving.....	
Wool bale breaking, blending, sorting.....	
Wool inspection.....	
Wool carding, drawing, sizing, twisting, spool winding.....	
Spinning white.....	
Spinning colored.....	
Weaving white.....	
Weaving colored.....	
<b>Paper industry</b>	
Breaking and beating, calendering.....	300-150 400-200
Paper machines, cutting, machining, refining.....	600-300 800-400
Paper machines – wet end.....	400-200
Paper machines – dry end, inspection,	

laboratories..... Manufacturing hall.....	
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