BEST PRACTICES IN ENERGY EFFICIENCY

Lighting

LIGHTING | ELECTRIC MOTORS | COMMERCIAL REFRIGERATION | AIR CONDITIONERS

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Energy efficiency

The costs of electricity generation and average demand are raising worldwide, this, in the face of greater competitiveness and socioeconomic development. The urgency of increasing the installed capacity of the interconnected systems to meet the electrical needs of the different consumer sectors is motivating the implementation of cost-efficient actions in the end-use of electricity.

The electrical equipment used in most industrial processes and in commercial installations generally has low levels of efficiency. In addition, the installed equipment has often exceeded its useful life or is approaching that limit, causing considerable energy waste and resulting in higher operational costs and higher greenhouse gas emissions as a consequence of the growing use of imported fossil fuels in the production of electrical energy.

This Manual is based on the set of activities the the Energy Network Foundation (Fundación Red de Energía or BUN-CA, in Spanish) and the United Nations Development Programme (UNDP), with funding from the Global Environment Facility (GEF), are developing under the *"Regional Energy Efficiency Program in the Commercial and Industrial Sectors in Central America"* (PEER), an initiative that is helping to remove barriers to knowledge and technical information toward the development of markets for efficient electrical equipment in Central America.

The objective of this series of publications for "Best Practices in Energy Efficiency" is to strengthen technical knowledge, by offering a thematic series of best practices on the topics of lighting, air conditioners, electric motors and commercial refrigeration, to promote electrical energy savings mainly in the industrial and commercial sectors.

1. Lighting systems

There are two main sources of lighting: natural light from the sun-light and artificial lighting using electricity.

Natural light has the best quality but its use is subject to factors such as effective hours of sunlight, season of year, weather status and architectural design of the installations.

In fact, it is recommended that all new buildings consider the contribution of natural light, to integrate it with artificial lighting and air conditioning.

Artificial lighting is a fundamental lighting need solution and its generalized use is extended to residential, industrial, commercial and service sectors where a wide variety of lighting system alternatives can be found, according to end-use requirements.

In general, artificial lighting systems consist mainly of four devices (Figure 1):

1. Lamp or light bulb: a source of light such as an incandescent bulb, linear fluores cent, compact fluorescent lamp (CFL), or other.
2. Ballast: an electromagnetic or electronic device that supplies current and tension for the fluorescent light type.
3. Light fixture: equipment that provides structural, aesthetic and optical light control functions.
4. Control: the device that turns lights on or off, manually or automatically.

Figure 1. Lighting system devices.

These devices work in harmony to produce the desired lighting effects. The lighting system should provide the level of lighting necessary, avoid undesirable glare, faithfully reproduce the colors of objects and emphasize their shapes and textures, creating a suitable environment for users and their activities.

2. Fundamental concepts of lighting systems

There are important parameters of lamps that an electricity consumer should know, (Figure 2):

Luminous flux: Any lamp generates radiant energy in the form of light, which is called luminous flux and it is measured in lumens (Lm). A lumen is a unit of light power; one Watt (W) has 683 lumens.

Efficacy: Lamps have the capacity to convert electricity into visible light. The quality of the light emitted is divided by the power used (W), to determine its efficacy. This quality is expressed as Lumens per Watt (Lm/W), a measure of the energy efficiency of the lamp.

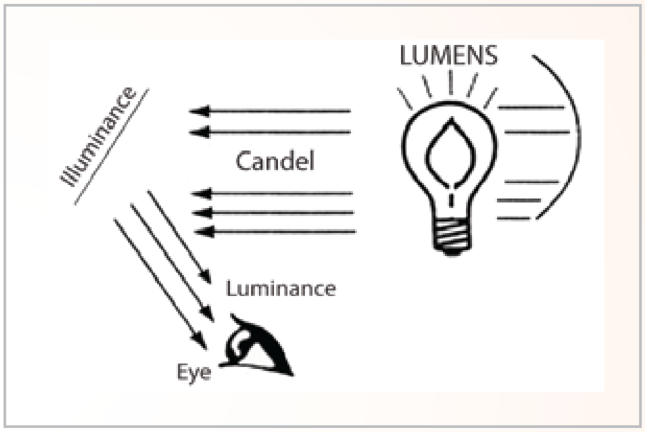

Figure 2. Lighting system

Luminous intensity: If it is placed an aluminum reflector around a lamp, the light will be concentrated in a particular direction. The total lumens emitted cannot change much but the luminous intensity, which is the concentration of light in a particular direction, can vary considerably. Luminous intensity is measured in candls (Cd).

Illuminance: When light hits a surface it creates illuminance on that surface. This, then, is a measure of the luminous flux that is incident on a surface, per unit area; it is measured in Lux (Lx).

Luminance: is the relationship between luminous intensity and the apparent surface seen by the eye in a determined direction. Its unit of measure is candls per square meter (cd/m2).

Color Rendering Index (CRI): The colors of objects appear different under different kinds of light. The CRI is a measure of the capacity of the lamp to make colors appear natural, on a scale of 0 to 100. Generally, the higher the CRI, the better the colors of objects appear. An incandescent bulb and natural daylight have CRIs of 100.

Color Temperature (CT): In a light source, color temperature is defined by comparing its color in the light spectrum with the light emitted by a blackbody heated to a determined temperature. That temperature is generally expressed in Kelvins (K), and bears no relation to the real temperature of the lamp (Figure 3).

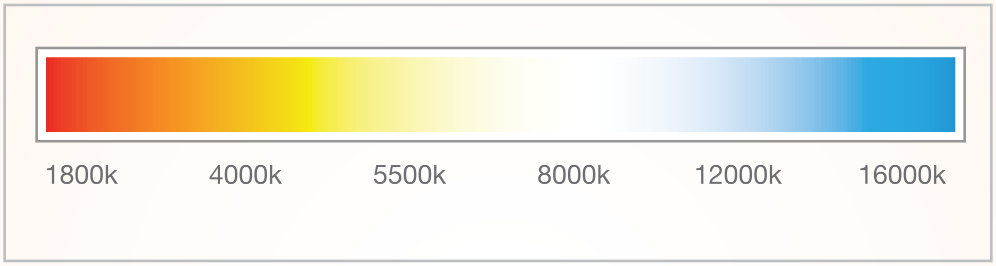

Figure 3. Color temperature scale.

3. Main types of lamps

Conventional incandescents
These are the most common kinds of lamps in developing countries, but they are energetically more inefficient, since they have evolved very little over the years (Figure 4). Conventional incandescent lights have qualities that have made them very popular for the last 100 years, but their disadvantages outnumber their advantages.

Figure 4. Incandescent bulbs.

For example, their initial cost is very low, they have good light quality, they are easy to obtain and their installation is very simple; however, their operation costs are very high, since they are short-lived and their efficiency is very low. These electrical devices produce excessive heat in nearly all applications, for example, requiring air conditioning units to work harder to acclimatize the space (Figure 5) and notably increasing total power and electricity consumption in the installations; moreover, they are very vulnerable to surges and variations in electrical current.

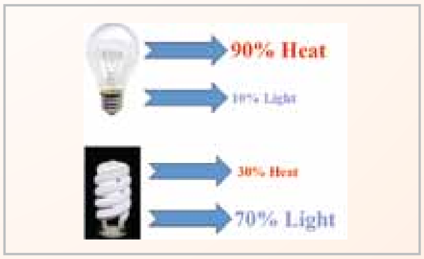

Figure 5. Energy efficiency.

Halogens

These are improved incandescent lights that are longer-lived than conventional incandescent ones (Figure 6). In almost all cases they are used to directly illuminate points and accent specific objects. This type of lamps includes the latest technology called IRC (infrared coating), which increases efficiency up to 65% over conventional incandescents and up to 30% over standard halogen lamps. One important consideration is the use of ultraviolet radiation filters (UV STOP) with halogen IRC lamps because they tend to produce radiation that can harm materials and human health, mainly in cases of prolonged exposure.

Figure 6. Halogen lamps.

Linear fluorescents

These are gas discharge lamps that consist of a closed glass tube containing noble gases, phosphorus and a small amount of mercury. They are manufactured with power ranging from 4 to 215 watts and are available in several bulb shapes (straight, circular, U-shaped) with diameters expressed in eighths of inches: 12/8” (T12), 8/8” (T8), 5/8” (T5) (Figure 7). The smaller the diameter, the greater the efficiency of the linear fluorescent.

In contrast with incandescent lamps, all fluorescents require a ballast to function. Electronic ballasts are more expensive than electromagnetic ones, but they are recommended for their superior energy performance.

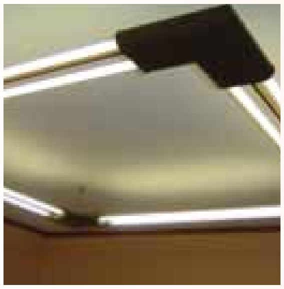

Figure 7. Linear fluorescent lamps.

Compact fluorescent lamps (CFL)

These type of lamps use a technology similar to that of linear fluorescents and they were originally designed as substitutes for incandescent lamps. They are available from 3 to 120 watts, in multiple shapes such as straight or curved tubes, bullet, ventilator, globe, reflector, spiral, etc (Figure 8).

These have the major advantage of directly substituting incandescent lamps without the need for any special installation and they have energy savings of 60% to 80%. They also have a useful life that is 5 to 20 times longer than incandescents and they do not produce excessive heat that can increase electricity consumption of air conditioning equipment.

Figure 8. Compact fluorescent lamps.

Light emitting diodes (LED)

LEDs are solid-state semiconductor devices that are very robust, reliable, vibration-resistant and long-lived. The interior of an LED is a small semiconductor encapsulated in a special resin (Figure 9). They are manufactured in bright colors that range from red to orange, yellow, green, blue and more recently, white.

Figure 9. Light emitting diodes (LED).

White LEDs are available in different tones of white light, from very warm to very cold. Given their long life, they are highly recommended for continuous operation applications, such as emergency and exit signs. Some of their best known applications are in cellular phones and the rear lights of modern cars. LEDs can also be attenuated with a relatively simple control (dimmer).

In order to compare the different kinds of lighting systems that can be installed, Table 1 presents a summary of the parameters of each system, according to the type of lamp to be installed.

Table 1. Lamp parameters by type

Parameters	Conventional incandescent	Halogen	Linear fluorescent	Compact fluorescent
Power (W)	3-1,500	3-1,500	4-215	4-40
Efficacy (Lm/W)	6-24	18-33	50-100	50-80
Life (hrs)	750-2,000	2,000-4,000	7,500-24,000	8,000-20,000
IRC	98+	98+	49-92	82-86
Useful life (hrs)	750-1,500	2,000-5,000	9,000-36,000	3,000-15,000
Maintenance of luminance	good/excellent	excellent	reasonable/good	good

Source: BUN-CA, 2006.

4. Why use efficient lamps?

The key to energy efficiency in lighting is identifying the quantity and quality of the illumination needed in each environment, interior as well as exterior. One strategy for the efficient use of lighting systems is to refer to the lighting levels recommended for the activities to be developed (see Table 3).

Excessively lit zones offer better opportunities for savings, while areas with low light levels should be redesigned, seeking a balance between lighting levels and energy consumption.

One action that always gives good results is the elimination of inefficient lamps, for example, conventional incandescents and T12 fluorescents. The use of electromagnetic ballasts and light fixtures that are at the end of their useful lives or in poor condition should also be avoided.

Although more efficient lamps such as compact fluorescents have a higher initial cost than incandescents, the energy savings are substantial and the investment recovering period tends to be 1 to 3 years, depending on the hours of use and electrical tariffs. Another advantage of efficient lamps is their longer useful life, from 5 to 15 times longer than conventional incandescents.

In selecting compact fluorescent lamps to substitute incandescents, the equivalent luminous flux should be considered, according to Table 2.

Table 2. Relationship between the power of incandescent lamps and compact fluorescent lamps (in W)

Incandescent bulbs	Compact fluorescents
25	5 - 7
40	8 - 11
60	13 - 15
75	18 - 20
100	23 - 25

Source: BUN-CA, 2006.

5. How are lighting needs identified?

Table 3 presents a basic tool for identifying the general lighting needs of different areas. Note that these are general recommendations and in no way they pretend to substitute the expertise of a specialized designer.

Table 3. Identification of lighting needs for some areas.

Areas	Description/activities	Recommended lamp types
Stairways, hallways	Lighting in these areas may need to remain lit for 24 hours; efficient lighting can save a lot of energy.	Compact fluorescent lamps are a very good option, although T8 and T5 fluorescents are also suitable for these areas. Substituting incandescents for fluorescents can save up to 80% of the energy, with a very rapid investment recovery of 6 to 12 months, due to the 24-hour/day operation.

Rooms	Rooms require a lighting system that ensures comfort during several visual tasks including reading, relaxing and watching television.	'Warm white' compact fluorescents at 2700K offer a quantity and quality of light very similar to that of incandescent bulbs, but they use up to 75% less energy.
Bathrooms	Lighting in bathrooms should provide conditions suitable for shadow-free decoration and allow skin tones and clothing colors to appear as natural as possible.	High quality compact fluorescent lamps reproduce colors acceptably and are suitable for bathrooms, although they can be combined with halogen IRC UV STOP lamps. Energy savings can vary from 30% to 75%.
Kitchen	The kitchen area should be well lit to ensure proper food preparation, minimize the risk of accidents and facilitate order and cleanliness.	T8 and T5 fluorescent lamps are suitable for kitchens; however, closed lights are preferred to prevent contamination in the event of lamp rupture. Lamps with bluish-white color temperatures at 5000K or higher, are preferred in these areas. There can be energy savings of up to 80% over incandescents.
Laundry room	The laundry room area should be well lit to minimize the risk of accidents and to provide good maintenance to electromechanical equipment and devices.	T8 or T5 fluorescent lamps are preferred in these areas, with bluish-white color temperatures at 5000K or higher. Open industrial type lamps can be used in the laundry room.
Exterior spaces	Exterior lighting should create a good impression to attract people and also give a sensation of comfort and security.	Metal halide lamps (metallic additive vapor) and other high intensity discharge (HID) types, such as high pressure sodium vapor, offer energy savings of 75% to 90% if installed instead of incandescent lamps.
Reception areas	The reception area represents an establishment's atmosphere. Lighting there should accent decorative details and other interior design characteristics.	Up to 50% of the energy can be saved if halogen IRC and UV STOP technology lamps are used. It is very important that the appropriate power is selected and the light surface offers the desired effect in accord with the object to be illuminated, considering the distance from it to the lamp.
Conference rooms	Conference rooms require different levels of lighting for different occasions, from sales presentations to wedding and birthday receptions.	Dimmable (variable intensity) halogen lamps produce a brilliant white light that can accentuate crystal, porcelain and candelabras. They can be combined with 'warm white' T8 or T5 fluorescents (3000K) to give high levels of lighting with very low energy consumption.

Restaurants and bars	Lighting needs in these areas vary according to the occasion (a well-lit atmosphere for meetings or a half-lit one for relaxation).	Dimmable halogen lamps with IRC and UV STOP technology in combination with 'warm white' to 'cool white' T8 and T5 fluorescents are recommended for creating scenes according to need and controlling light levels and colors. Energy savings can also exceed 50%.
Support areas	Support areas such as personnel lounges, storage areas and office spaces rarely require lighting for 24 hours per day, but because of the nature of their users, there is often energy wastage.	'Cool white' T5 or T8 fluorescent lamps (at 4100K) are suitable, mainly if they are operated with good quality electronic ballasts and well designed light fixtures for each application. The use of occupancy sensors can offer major energy savings (up to 50% in some cases).
Orientation	Exit signs and other orientation signals that operate all day in a hotel are major consumers of energy.	LEDs (light emitting diodes) are very efficient in these applications, because they can achieve energy savings of up to 90% and can last up to 10 years in continuous operation without the need for replacement.
Warehouses	Warehouses are incorporating new technologies and lighting is no exception. Illumination with suitable technology can reduce energy costs and improve employee performance by minimizing errors in the tasks they carry out.	T8 or T5 fluorescent lamps are ideal for warehouses or storage areas. Depending on the height of the place, metal halide lamps (metallic additive vapor) and other high intensity discharge (HID) types can also be used.
Offices	Work areas are settings where a wide variety of visual tasks are carried out and where employees spend most of the day in artificial lighting. The use of computer screens requires minimum reflection and light contrasts that ensure visual quality and safety for the workers.	T8 or T5 fluorescent lamps are preferred in these areas, with bluish-white light tones at 5000K or higher. Open industrial-type lamps can be used.
Production areas	The purpose of lighting in an industry is to provide light in sufficient quantity and quality for safety, visibility and productivity in a pleasant environment.	T8 or T5 fluorescent lamps can be used and, depending on the process and the environment, they can be combined with other high intensity discharge lamps as well. If necessary, localized lighting in the work area can be a viable, more economical option.

Source: USEPA. Putting Energy Into Profits, Energy Star Guide and Green Hotelier Magazine, Issue 28. Holland.

6. Best practices for saving energy

- **Use more natural light.** Open the curtains and blinds to make maximum use of natural light during daytime operations as allowed.

- **Prepare a maintenance and cleaning plan for lamps and light fixtures.** Lighting quality is diminished if the lamps and fixtures are not clean. Layers of dust on lamps and reflectors diminish light emission and these should be cleaned at least once per year. Fluorescent lamps lose luminosity as they age. They should be replaced according to the manufacturer's technical specifications so as not to waste energy. Modern fluorescents, such as T8 and T5, have better luminosity throughout their useful lives.

- **Replace magnetic ballasts with electronic ones.** All fluorescent lamps need ballasts to provide the proper voltage and current. Electronic ones operate at lower temperatures and have longer useful lives; in fact, they increase the efficiency of the fixture from 12% to 30% and also eliminate flickering and noise.

- **Use light colors on walls, ceilings and floors.** Light colors reflect more light in interior spaces. An appropriate color selection for walls, ceilings and floors, can reduce lighting needs considerably.

- **Install a smart lighting control system.** To take maximum advantage of artificial lighting, "smart" controls can be employed to optimize lighting use, including occupancy or natural light sensors, dimmers, timers or some combination of these.

- **Turn off lights that are not in use.** In areas with well-established fixed schedules, use of artificial lighting should be reduced as much as possible.

- **Use work lights.** For certain tasks, background lighting can be reduced and one light can be focused on the specific work point, for example, on office desks or reading tables.

- **Replace incandescent bulbs with compact fluorescent ones.** Fluorescent light is more economical over the medium and long term; nearly every bulb can be substituted without any notable change in the existing installations. Standard compact fluorescent lamps cannot be dimmed or used with dimmers. However, it is now possible to acquire models designed specifically for use with dimmers.

- **Install linear fluorescents for general illumination**. If one is planning to remodel and/or build, anticipate installing linear fluorescent light fixtures, preferably with quality electronic ballasts backed by at least a five-year written guarantee.

- **Seek alternative energy sources.** There are other means of providing the illumination required, such as lamps that use a photovoltaic cell and a battery and avoid wiring and use of current from the main source, for example, for lights along trails.

- **Consider efficient lighting technical standards.** When buying new equipment, take into account the technical standards and energy efficiency labeling for the lighting systems developed in each country, which specify minimum performance indices and direct one to the acquisition of more efficient equipment. To reference the technical standards, consult the national standards entity in each country.

Other Notes
(include other useful practices here in your particular context)

For more technical information on energy efficiency, visit our Web page at
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