POWERING HEALTH: EFFICIENT LIGHTING AND LEDS

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POWERING HEALTH

This document is provided as part of USAID's Powering Health toolkit. Health-care facilities require electricity to maintain perishable supplies and power life-saving technologies. Energy is essential for preventing child and maternal deaths, controlling the HIV/AIDS epidemic, and combating infectious diseases and pandemics.

Reliable electricity can mean life or death for patients in developing country health-care facilities. However, many of these facilities have little or no access to reliable electricity. USAID supports partner countries in understanding the energy needs of their health-care facilities over the long term. This challenge requires local capacity for careful planning, a commitment to maintenance, and dedicated funding.

USAID uses its experience at the nexus of the health and energy sectors to help international development practitioners and health-care administrators design programs that meet the energy needs of health-care facilities. By applying international best practices and lessons learned, stakeholders can help ensure that health-care facilities are able to power standard appliances, such as lights, life-saving equipment, blood and medicine refrigerators, ventilators, laboratory diagnostic tools, and technology that monitors patients' vital signs.

INTRODUCTION

Health facilities of all sizes benefit from lighting that increases energy efficiency, reduces maintenance costs, and improves environments. Light emitting diode (LED) lighting technologies can provide most indoor and outdoor lighting.

LEDs have rapidly moved into the mainstream lighting market. Their availability and range of applications will continue to expand while their cost decreases. Long life and low energy consumption are the hallmarks of the LED, but the quality of light, in terms of color temperature and color rendering, is also quite good and can be designed to meet specific lighting demands.

This document explores efficient lighting technologies for healthcare applications, with a special focus on LEDs. This document provides a technical discussion on lighting specifications and technologies for health-care applications, an overview of lighting demands in the health-care environment, and practical considerations regarding financial analysis, retrofit implementation and monitoring, and standards and procurement.

LIGHTING METRICS

When assessing the applicability of different lighting technologies, a number of parameters should be considered, including efficacy, correlated color temperature (CCT), and lifetime.

EFFICACY (LM/W)

Manufacturers commonly describe the energy efficiency of lighting in terms of efficacy or lumens of light produced per watt of energy consumed (lm/W). Efficacy varies widely among the various lighting technologies. Improving efficacy is normally the primary goal of a lighting retrofit, as it results in energy savings.

COLOR RENDERING INDEX (CRI)

The color rendering index (CRI) of a lamp measures its ability to accurately reproduce colors on a scale of 0 to 100, with 100 representing the most accurate color reproduction. Incandescent lamps, by definition, have a CRI of 100. Typically, LEDs and compact fluorescent lamps (CFLs) have a CRI upward of 75.

CORRELATED COLOR TEMPERATURE (CCT)

The correlated color temperature (CCT) describes how "warm" or "cool" the light produced by a particular lamp appears. Most incandescent lights produce a "warm" color around the range of 2,700 Kelvin (K) to 3,500 K. Many CFLs have a neutral color of 3,000 K–4,100 K. LED lamps often produce a very "cool" color (>5,000 K), but many LED lamps designed to replace incandescent lighting also produce light within the "warm" range (<3,500 K). CCT is associated with an environment's "mood," affecting comfort and alertness.

LIFETIME (HOURS)

Lighting technology lifetime is measured in hours. Longer lighting lifetime generally results in reduced maintenance costs. LED lifetime is the longest of any lighting technology, lasting upward of 35,000 hours. CFL lifetime is typically around 12,000 hours. Because of its maintenance implications, lifetime is important to cost savings for maintenance-intensive applications such as municipal lighting and some medical devices.

LUMINOUS FLUX (LM)

The amount of light created by a lamp or fixture, measured in lumens (lm).

ILLUMINANCE (FOOT-CANDLE) OR (LUX)

Illuminance is the luminous flux measured at a particular surface (rather than measured at the source), and is given in foot-candle or lux (lumens per square meter (lm/m_2)). Illuminance is the critical parameter when determining how much light is available for reading, typing, or other tasks. Illuminance is affected by a variety of factors, including the luminous flux of the light sources, the position of the surface relative to those sources, and the color and materials of the surroundings. The Illuminating Engineering Society (IES) publishes illuminance standards for particular workplace tasks.

LENS/BULB TYPE

All traditional lighting technologies employ bulbs or tubes, while lighting fixtures often have additional lenses or coverings, even LED fixtures. These bulbs and lenses reduce luminous flux but may also help to diffuse the light source, making it more comfortable to look at. The correct choice of lens or bulb is a matter of task requirements, retrofit or spatial constraints, and taste.

MOUNTING BASE

The mounting base of a lamp provides the physical interface with the lighting fixture that ensures an electrical connection and holds the lamp in place. There are a large number of mounting bases in use that vary by technology and application. Some of the more recognizable mounting types are the "Edison" screw-type base common to incandescent bulbs and the G13, or medium bi-pin type, used in linear fluorescent tubes. Retrofit lamp replacements must ensure mounting base compatibility with existing fixtures.

LIGHT EMITTING DIODES (LEDS)

CREE LIGHTING

Light emitting diodes are a solid-state lighting (SSL) technology that is fundamentally different from other, traditional lighting technologies such as incandescent or fluorescent. Diodes—semiconductor devices—are a common element of all modern electronics. Rather than sending signals in a computer circuit, a light emitting diode produces photons—light. LED lighting differs from traditional lighting because there are no gasses involved; it is a solid-state lighting technology. This key difference results in a number of advantages, discussed in the next section, compared to older technologies.

Although LEDs are the advanced form of solid-state lighting, other SSL technologies have started to become available in the market, such as the organic light emitting diode (OLED). OLEDs differ from traditional LEDs in that they utilize organic compounds (typically a polymer), in place of silicon. OLED technology promises several advantages over LEDs, such as lower cost, higher efficacy, and mechanical flexibility.

As a fundamentally different type of lighting technology, LEDs command a number of advantages over traditional technologies. The following table summarizes the efficacy of various traditional lighting technologies and their LED alternatives.

The primary advantage of LED lighting is high efficacy, which arises from its low-temperature operation. Traditional lighting technologies, especially incandescent, rely on heat in order to generate light; thus, much of the energy used in their operation is lost as heat. Light emitting diodes create very little heat as their light output results from electrical current rather than thermal energy. The following table summarizes the efficacy of various traditional lighting technologies and their LED alternatives. In health facilities, the beneficial consequences of cool operating LEDs are decreased facility cooling loads and more comfortable environments for practitioners working in the vicinity of medical lights.

COMPARISON OF LIGHTING TECHNOLOGIES

LUMENS	LED	COMPACT FLUORESCENT	INCANDESCENT
400–500	6–7 W	8–12 W	40 W
650–850	7–10 W	13–18 W	60 W
1000–1400	12–13 W	18–22 W	75 W

Source: Adapted from https://www.viribright.com/lumen-output-comparing-led-vs-cfl-vs-incandescent-wattage/

The long lifetime is another key advantage of LED lighting and a major driver of cost savings in LED retrofits. Well-designed LED fixtures will typically last 35,000 to 50,000 hours or more, considerably longer than other lighting technologies. This translates to reduced maintenance and replacement costs over the life of a lighting system, an especially important factor in high-maintenance applications such as street lighting and medical lighting.

LEDs are also different from other lighting technologies in that they emit unidirectional light. Traditional lighting emits light in all directions; that light must then be directed toward targeted areas (*e.g.*, desks, streets, and operating tables) by reflectors. LEDs emit light in only one general direction, allowing them to deliver light to targeted areas more efficiently. LEDs can use this advantage in medical lighting, where focusing light on a specific location is often of great importance.

LEDs also have an advantage over traditional lighting technologies in how they respond to voltage fluctuations. Inconsistent power quality plagues electrical grids in many developing countries. Generator power, too, is responsible for spikes and surges in voltage. Medical equipment and lighting are sensitive to these voltage fluctuations. Halogen lamps, the traditional light source for most medical lighting, are especially sensitive and prone to frequent blowouts due to unstable power supply. By contrast, LED lighting is better able to endure voltage fluctuations. Rather than experiencing a complete blowout, LEDs take a penalty in lifespan when subjected to poorly regulated voltage. So while the quality of power supply is still important for LEDs, the risk of complete light failure due to unstable voltage is less than with halogen lamps.

RELATED EQUIPMENT

Lighting technologies are commonly differentiated by their light source or lamp type, but there are a number of other components that are needed to create efficient and aesthetic lighting. When specifying lighting systems (lamps, fixtures, ballasts, and controls), it is important to ensure that all components are compatible. For example, fluorescent lamps will differ in their mounting base, size, and ballast compatibility, all of which affect the selection of luminaires and controls.

LUMINAIRE/FIXTURE

Beyond the light-producing lamp, other components are needed to create a functional light source, including ballasts or drivers, electrical wiring, structural members, light reflectors, and lenses. These components (including the lamp itself) are collectively called the luminaire or light fixture. Luminaires will differ greatly in their form and function, based on the tasks or areas they are designed to illuminate. Street lights, medical exam lights, 2’x4’ troffers, and track lighting are all examples of luminaires designed for very different lamp types and applications.

U.S. DEPARTMENT OF ENERGY

DRIVERS

LEDs must receive a precisely regulated electrical current from a driver. A driver is a piece of electrical equipment that regulates the electrical current sent to the lamp. In the case of LEDs, a driver provides a direct current (DC). Drivers consume a small amount of electricity on their own, which should be added to lamp wattage.

LIGHTING CONTROLS

Broadly, lighting controls consist of switches, timers, dimmers, sensors, and even energy management software. While a control may be as simple as an on/off switch, more advanced devices are used to optimize lighting usage and limit consumption. Controls can lead to significant energy savings by reducing lighting operational hours. This is often accomplished through timers or occupancy sensors that turn off or dim lights based either on a set schedule or the presence of occupants.

HEALTH FACILITY LIGHTING

Health facilities vary according to their size and services. Small clinics may provide only basic health services, requiring minimal electrical equipment and low lighting loads. By contrast, large medical facilities are among the most energy-intensive building types, providing specialty medical services, laboratories, and in-patient treatment. Health-care lighting is therefore expected to meet the demands of diverse environments and applications.

Electrical loads typically seen in small health facilities include lighting, vaccination refrigeration, and radio communications equipment. Lighting at a clinic may include general indoor lighting, outdoor security lighting, and laboratory lighting such as microscope lights. Since energy resources are often limited or expensive for small facilities, energy efficiency is of great importance. LEDs can play a prominent role in achieving greater energy efficiency in such facilities because lighting makes up a greater proportion of total energy consumption when compared to larger facilities.

For facilities that employ solar photovoltaics and backup battery banks, the efficiency of LEDs can impact energy system costs significantly. Alternatively, a reduction in lighting load can allow for the use of more laboratory equipment. The bottom line is that energy efficiency measures, like the use of LEDs, allow for a reduction in energy system size (*i.e.*, generation and storage) or an expansion of energy-dependent health services. For example, lowering facility lighting consumption may allow for more vaccine storage or the use of basic laboratory equipment such as a centrifuge. In this regard, LED technology has a direct effect on the quality of health care delivered at the facility.

Lighting also takes on new importance in laboratory settings, as lab work depends on good lighting. Even during the day, laboratories and exam rooms require artificial light in order to achieve the illumination levels necessary for critical tasks. LED lighting is capable of providing general illumination for such spaces, as well as dedicated task lighting. Most medical lighting equipment, such as microscopes and exam lighting, is available with LEDs, which save on energy and maintenance costs while providing exceptional lighting quality.

In-patient facilities such as large hospitals, especially those with emergency care, operate 24/7. LED lighting can provide greater benefits in facilities under constant operation, both in terms of energy consumption and occupant well-being. First, the absolute energy savings attainable through the use of LED lighting increases as the lighting operational hours increase. Areas that require 24-hour lighting yield the greatest savings from a conversion to LED lighting, especially when the maintenance needs of LEDs are compared to those of typical fluorescent lamps. Second, the light output of LEDs is nearly full spectrum light, much more so than light from fluorescent lamps. Full spectrum light more closely resembles daylight and has been shown to help maintain proper sleep schedules. The high-quality light from LEDs can enhance the health of patients and the awareness of facility personnel, especially those who work at night.

LEDs also have superior dimming capabilities. While other lighting technologies also have the ability to dim, the process is less complex for LED lights. This is because the light output of an LED is proportional to the electrical current that it is supplied. To dim an LED, simply lower its current. This makes dimming capabilities for LEDs less expensive and more flexible than for other lighting technologies. Dimming is quite useful for health-care lighting and can be applied in general lighting for corridors and patient rooms and in surgical lighting, providing another level of control to surgical teams.

PRODUCT SELECTION

Many LED products have entered the market, but since this type of product is relatively new, claims regarding lamp life, lumen output, and color characteristics may be unsubstantiated. Furthermore, electronic systems supporting the LEDs (*i.e.*, driver, heat sink) will also affect the overall product.

If possible, third-party testing of the LED lighting system should be conducted, and designers should reference lighting standards when specifying lighting systems. The following standards are particularly relevant to LEDs: IES LM-79-19 (photometric measurement of LEDs), IES LM-80-20 (measuring luminous flux and color maintenance of LED), and IES TM-21-11 and Addendum B (projecting long-term lumen maintenance of LED light sources). A manufacturer's warranty of at least three and preferably up to five years is also highly recommended. For medical lighting in particular, a period of trial usage, allowing for personnel feedback, is common. Whether selecting LEDs for general lighting or medical applications, taking the time to choose quality products ensures that the full potential of LED lighting is reached.

LIGHTING RETROFIT IMPLEMENTATION AND ANALYSIS

FINANCIAL ANALYSIS: LIFE-CYCLE COST (LCC) ANALYSIS

Since alternative options are available for nearly every medical and general lighting application, it is important to understand the different factors that play a role in the financial viability of those alternatives. For example, the increase in initial cost, reduction in wattage, and extended life of LED products influence their competitiveness with traditional lighting technologies. The cost of electricity and lighting operational hours also affect any financial comparison of technologies.

LED products are more likely to be competitive with traditional technologies in situations where the lamp experiences long operating hours, energy costs are high, and the lamp life of the traditional technology is short. Because initial cost, energy consumption, and lamp replacement costs are all important considerations in a lighting retrofit, any financial analysis should be performed on a life-cycle cost basis. By evaluating all associated lighting costs (capital, operation, replacement, and disposal) over a 10- or 20-year period, the full benefits of efficient lighting will be captured.

While each potential project must be assessed individually, the life-cycle cost components of a lighting retrofit typically include the following:

CAPITAL COSTS

Retrofit capital costs include equipment and installation costs and any costs associated with the design, planning, or periodic monitoring of the retrofit.

OPERATING COSTS

Operating costs are determined by the energy consumption of the new, efficient lamps. A kilowatt-hour (kWh) estimate of post-retrofit lighting consumption can be made by multiplying the wattage of each retrofit lamp by the total number of hours it operates each year and summing these consumption values for the entire facility. This consumption figure can then be multiplied by the facility's electricity tariff rate to yield the annual operating cost. High electricity rates and long operating hours typically result in faster retrofit paybacks.

REPLACEMENT COSTS

Sometimes the energy consumption of a particular application is low (*e.g.*, microscope lighting); lamp life may still be an important parameter in these cases. For example, while energy savings from an LED microscope are unlikely to make up for the increase in initial cost, the difference in replacement costs over time will make the LED lamp an attractive option.

DISPOSAL COSTS

All lamps and fixtures require disposal at the end of their life. This may represent an additional cost to the facility and is an especially important consideration with fluorescents, which contain small amounts of mercury. Depending on local regulations and the number of lamps being discarded, these lamps may require special disposal measures at added expense.

Note: Disposal costs will also be incurred at the outset of a retrofit as old lamps are replaced with efficient retrofit lamps. This initial disposal cost, while important to the project's budget, should not be considered in the LCC analysis unless the old lamps would not otherwise require replacement.

TECHNICAL ANALYSIS: LIGHTING AND POWER LEVELS

Proper lighting levels are important in a hospital setting, not only to the work of doctors, nurses and lab technicians, but also to provide a safe and comfortable environment for patients. Light levels are measured at particular working surfaces with a light meter, which records the illuminance at that surface (in foot-candles or lux). Energy consumption may be logged over time or calculated based on measured lighting loads and observed operational hours.

The potential for energy cost savings forms the basic rationale for most efficient lighting retrofits. A quantitative and systematic measurement of light levels and power consumption is needed in order to justify the retrofit costs with energy savings. The measurement methodology will be laid out in a monitoring and evaluation plan (see below), which specifies how, where, and how frequently light levels and lighting consumption will be measured. Such a plan dictates that measurements are taken before the retrofit, and at least once after, in order to determine energy savings and make a proper comparison of light levels.

OCCUPANT SATISFACTION

Occupant satisfaction is another important factor in an efficient lighting retrofit performance. Typically, retrofits are designed to meet or exceed pre-retrofit light levels. While light measurements provide a quantitative way to gauge occupant satisfaction, other factors relating to light quality, such as glare, color, and uniformity also play an important role. Judging occupant satisfaction in a qualitative manner, through staff surveys, supplements the measured lighting levels as an indicator of the project's success.

MONITORING AND EVALUATION (M&E) PLAN

In order to effectively gauge the success of the lighting retrofit, a systematic, repeatable, and quantitative monitoring and evaluation plan must be carried out. This plan focuses on pre- and post-retrofit light-level measurements and electrical load data logging. Load logging will preferably target only the retrofit fixtures, although facility-level data may also be used to estimate actual savings. This data allows for an initial assessment of retrofit success and provides the foundation for continued monitoring. On a periodic basis, lighting and facility load data should be collected in order to evaluate the ongoing operation of the efficient lighting. Occupant surveys may also be continued each year for comparison to the initial post-retrofit survey. The intent of these monitoring activities is to replicate the baseline measurements following routine procedures such as those listed below:

- A lighting inventory should be performed, counting and estimating the wattage of all existing lighting. This is also an opportunity to register failed lamps and take stock of the supply of replacements.
- Ideally, consumption data is logged for at least one week, allowing for a comparison based on weekly and hourly operating conditions (e.g., weekdays vs weekend).
- Light-level measurements should be taken at specific working surfaces during each monitoring visit. It is helpful to mark on a floor plan where measurements were taken so that they may be replicated.

The occupant survey may also be replicated, asking similar questions and engaging similar facility occupants. The goal will be to gauge the occupants' perception of the efficient lighting over time and ensure their continued satisfaction.