Article #11, May 23, 2006
AJ's Technical Tips: Technologies for Lighting in Rural Africa
by Arne Jacobson

People living in off-grid areas in Africa use a variety of different technologies for lighting. I will use this article to compare and contrast some of the more common lighting technologies. I will focus especially on the potential of white LED lights, which are an important and newly emerging lighting technology.

Kerosene lamps are by far the most common type of light used in Sub Saharan Africa. For example, survey data from a few years back indicate that 92% of rural Kenyan households use kerosene lamps, while only 8% use grid power or solar electricity for lighting. Among those that do have electric light, about half are connected to the grid and half use solar electricity. Note that the 8% figure does not include battery powered torches (also know as flashlights). The survey data indicate that 52% of rural Kenyan households own at least one electric torch. Candles are also common, although relatively few households use them as their main source of lighting.

Although kerosene lamps are more common, nearly everyone prefers to use electric light if they are able to do so. One of the reasons that people prefer electricity is that it can be used to produce a brighter source of light than kerosene or candles. The “brightness” of a light can be measured in terms of “lumens”. A lumen is the unit of measure of the “luminous flux” of a lighting source. In other words, while electric power is measured in watts, the amount of light produced by a source is measured in lumens. Brighter lighting sources have higher lumen values, while dimmer sources have lower values. Table 1 shows typical lighting output values (in lumens) for several different lighting technologies.

Table 1. Typical Lumen Efficiencies for Selected Lighting Technologies

Light Type	Typical Watt Rating	Typical Light Output (lumens)	Lumen Efficiency (lumens/watt)
Candle	n/a	10 lumens	0.2
Kerosene Lamp (simple wick)	n/a	10 lumens	0.1
Kerosene Lamp (hurricane style)	n/a	30 lumens	0.1
Incandescent Bulb	15 W	225 lumens	15
Fluorescent Tube Lamp	10 W	500 lumens	50
White LED Lamp	1 W	30 lumens	30

The data in Table 1 show that incandescent bulbs and fluorescent tubes generate many times more light than candles or kerosene lamps. In the case of a 10 Watt fluorescent tube light, the lighting output is approximately 15 times greater than the light from a hurricane style kerosene lamp. Figure 1 shows a room that is dimly lit by a hurricane style kerosene lamp.

Figure 1. A room lit by a hurricane style kerosene lantern (photograph by Evan Mills)

One measure of the efficiency of a lighting source is given by the amount of light produced (in lumens) per watt of power input. The values in the far right column of Table 1 show typical lighting efficiency values in units of lumens per watt. These efficiency values are sometimes called the "lumen efficiency" of a light. In the case of electricity, the watt rating that is used to calculate the lumen efficiency corresponds to the amount of electricity that is used by the light. In the case of the kerosene lamps, the lumen efficiency is calculated using a watt value that corresponds to the rate of kerosene use by the lamp.

The lumen efficiencies listed in Table 1 show that fluorescent tube lights are about 500 times more efficient than kerosene lamps, while incandescent bulbs are about 150 times more efficient. In other words, electric lights are not only brighter than kerosene lamps, they are also MUCH more energy efficient. Fluorescent lights have the highest efficiency among commonly used lighting technologies. When it comes to lighting up a room fluorescent lights provide the most efficient route.

The last lighting technology shown in Table 1 is a "white LED lamp". LED is short for "lighting emitting diode". In other words, LEDs are a special type of diode that produces light from electricity.

LEDs come in a number of colors. Colored LEDs are commonly used as indicator lights in electronic devices. For example, red, yellow, and green LEDs are often used in solar PV system charge controllers to show the condition of the battery.

White LEDs (WLEDs) are a relatively new technology, and they promise to play an increasingly important role in a variety of lighting applications. They are similar to colored LEDs, except that they produce a "white" colored light. They are already starting to be used in certain lighting applications, such as small electric torches (see Figure 2). In the near future, WLEDs will be used in many other types of lights.

Figure 2. Electric torches that use white LEDs are now available in Africa (photograph by Evan Mills).

As shown in Table 1, commercially available WLEDs can produce light at an efficiency of 30 lumens/watt. I should note that this value is for high quality WLEDs, as some lower quality brands do not perform as well. At the same time, it is also important to note that the efficiency of high quality WLEDs has been increasing rapidly. Leading research laboratories have reported efficiencies for WLEDs on the order of 100 lumens/watt, and this value is likely to increase still further over the next few years. This means that while the lumen efficiency of commercially available WLEDs is still below the 60 lumens/watt levels achieved by many fluorescent tube lights, it is likely that WLEDs will exceed these levels in the future.

It is also important to note that some fluorescent lights have a lumen efficiency that is less that 60 lumens/watt. For example, small three to five watt compact fluorescent lamps typically perform at about 30 lumens per watts, which is the same efficiency level as commercially available WLEDs. In other words, WLEDs are already as efficient as some types of fluorescent lights.

In addition, for certain applications the WLEDs that are available now can be even more efficient and more cost effective than fluorescent lights. The reason for this is related to the way that LEDs deliver light. While most lighting technologies, including kerosene lamps, incandescent bulbs, and fluorescent lights, produce light that is radiated in all directions, LEDs produce a focused beam of light (see Figure 3).

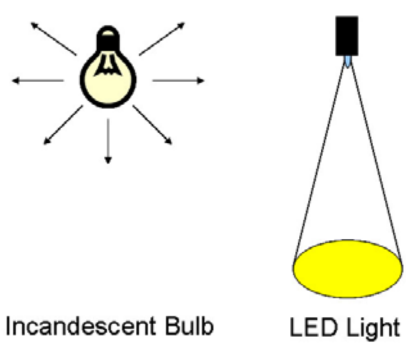

Figure 3. Most lighting technologies radiate light in all directions, while LEDs deliver light in a focused beam.

Because of their ability to deliver a relatively focused beam of light, WLEDs can provide good “task” lighting to a surface for a very small amount of electricity. For example, a one-watt white LED that produces 30 lumens of light can concentrate all 30 lumens onto a relatively small surface. A kerosene lantern might generate a similar amount of light (for example, 10 to 30 lumens), but the light is radiated in all directions. As a result, the amount of light from a kerosene lantern that reaches any one unit of surface area is smaller than in the case of a white LED.

In technical terms, the amount of light that strikes a surface per unit area is called the “lighting intensity”. Lighting intensity can be measured in terms of the number of lumens of light per square meter of surface area (l/m^2). This measure is called a “lux” (that is, one l/m^2 is equal to one lux).

The lighting intensity is what we care about when we use light for reading, writing, and many other important tasks. It is therefore useful to calculate the performance of lighting technologies in terms of the amount of light that they deliver to a surface per unit of electricity input. This measure can be called the “lux efficiency” of a light. Table 2 shows typical lighting intensity and lux efficiencies for several different types of lights.

Table 2. Typical Lux Efficiencies for Selected Lighting Technologies

Light Type	Typical Watt Rating	Typical Light Output (lumens)	Light Intensity (lumens/square meter or “lux”)*	Lux Efficiency (lux/watt)
Candle	n/a	10 lumens	1	0.02
Kerosene Lamp (simple wick)	n/a	10 lumens	1	0.01
Kerosene Lamp (hurricane style)	n/a	30 lumens	3	0.01
Incandescent Bulb	15 W	225 lumens	20	1
Fluorescent Tube Lamp with Reflector	10 W	500 lumens	60	6
White LED Lamp with Diffuser	1 W	30 lumens	40	40

*Approximate light intensity on a surface that is one meter away.

The information in Table 2 shows that a one-watt WLED can deliver almost as much light per unit area (40 lumens per square meter at a distance of one meter) as a 10 watt fluorescent tube light (60 l/m^2 at one meter). This impressive performance by the WLED gives it a lux efficiency of 40 lux/watt, which is more than five times the lux efficiency of a typical fluorescent light and about 4,000 times the lux efficiency of a typical kerosene lamp. These results highlight the potential of WLEDs for situations where a small amount of good quality light is needed in off-grid areas.

The value of white LEDs can also be shown through a practical example. My colleague Dr. Evan Mills visited a night market in Dar es Salaam, Tanzania. The vendors in the market used kerosene wick lamps to shine light on their wares (Figure 4). A one-watt WLED lamp provided much better light (Figure 5). The improvement in the lighting can lead to higher sales, as customers are able to see the products clearly and the sellers can maintain their light more easily under rainy or windy conditions. The cost of operating the WLED lamp is also lower than the cost of kerosene. Dr. Mills estimated that the vendor could recover the cost of the WLED lamp in less than a year due to savings from not having to buy kerosene.

Figure 4. Shoe kiosk lit with a kerosene wick lamp (photograph by Evan Mills).

Figure 5. The same shoe kiosk lit with a one-watt white LED that is equipped with a diffuser (photograph by Evan Mills).

As a second example, white LEDs can be used to make high efficiency electric torches. Here, the main benefit is the long life of the batteries. The dry cell batteries in a WLED torch can last five or ten times longer than the batteries in a regular electric torch. This can add up to considerable savings due to the high cost of dry cell batteries.

White LEDs can also be very useful for "task" lighting applications such as evening time studying by children in off-grid areas. A good-quality one-watt WLED lamp can easily provide enough light for reading. If the house has a solar PV system, the reading light can be used for many hours without draining the battery very much. For those who do not have solar, a one-watt WLED lamp could be powered for 80 hours using high quality dry cell batteries. There are many additional examples of applications where white LEDs can be an excellent choice.

An additional comparison between WLEDs and other lighting technologies is related to their durability and replacement lifetime. WLEDs are very rugged, and they can be used for 30,000 to 50,000 hours before it is necessary to replace them. This compares to 3,000 to 10,000 hours for most fluorescent lights and 500 to 1,000 hours for an incandescent bulb.

To summarize, in this article I compare some common lighting technologies, giving special attention to white LEDs. It should come as no surprise that electric lights are more efficient than kerosene, but there are also important differences between the different types of electric lamps. In general, fluorescent lamps are still the most efficient technology for lighting up a whole room, although WLEDs may catch up in a few years. At the same time, white LEDs are able to deliver a focused source of light while using a very small amount of electricity. This makes WLEDs the most promising lighting technology for activities ranging from evening time reading to illuminating a display in kiosk at a night market. With the exception of electric torches, WLEDs are not yet widely available in Africa. However, they should become more available over the next few years and I encourage you to keep an eye out for them.

In closing, I want to give special thanks to Dr. Evan Mills of Lawrence Berkeley National Laboratory in the USA. Dr. Mills is an expert in lighting technology, and I used several of his reports as information sources for this article. For more information, see http://eetd.lbl.gov/emills/PUBS/Fuel_Based_Lighting.html

Until next time, *kwa herini*.