

Rural Lighting Services

A Comparison of Lamps for Domestic Lighting in Developing Countries

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This Note is about the most optimal choice of lamps for improved lighting, mainly in rural areas in distributed applications i.e. in stand-alone (DC – Direct Current) as opposed to grid-connected (AC – Alternating Current) applications. Optimal has different meanings for different groups (users, scientists, project planners, etc.), and a balance is struck. Stocktaking of available lamps through technical tests provides baseline data. Recommendations for minimum quality norms are proposed.

The use of electricity to provide lighting services usually has very high priority among villagers. This is because electric lamps have major advantages over their nonelectric counterparts (such as kerosene lighting and candles), including increased levels of light, better quality light, greater ease of use, and lower cost per unit of light output. However, there are few incentives to apply energy-efficient lighting in conventional rural electrification (grid extension). Electricity tariffs are often low and do not provide strong incentives to choose the optimal lighting source. In addition, alternative more efficient lamps are either not available or consumers lack information about them. In contrast, when solar photovoltaics provide the electricity for rural lighting, the high cost of electricity per unit motivates

more careful selection of the lamp or high efficiency lamps are already included in the kit that comes with the purchase of a photovoltaic system. However, cheaper, less efficient types of electric lamps may be more appropriate under certain circumstances.

This Note is about how the results of technical tests on a range of lamps provide a guide to an optimal choice of lamp depending on the circumstances. New types of low-wattage electric lamps have entered the market in the last decade. These new applications and the changing focus of rural development planners toward photovoltaics (or rechargeable batteries) as a source of electricity prompted the present update of the state of the art in household lamps.

Suitability of Lights for Different Tasks

With information about the spatial distribution of luminous intensity it is possible to make qualitative statements about the suitability of different light types for different tasks. For orientation lighting, very low illumination levels of 5 lux (lumens per square meter) or below are acceptable. General lighting requires 10 to 50 lux, and task lighting at least 50 lux (Table 1). Lights with

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A traditional hurricane lantern

a lumen output of less than about 20 are usually suitable only for orientation lighting. Although most users want one or more orientation lights inside or outside their homes, the typical solar home kits do not include them because of their low-efficiency.

Laboratory Tests of Lamps

From mid- to late 1997 the Netherlands Energy Research Foundation (ECN) carried out a series of laboratory tests, focusing on measuring and comparing the light output characteristics and energy consumption of a number of different electric and nonelectric lamps. The results complement the lamp manufacturers' data sheets. ECN also evaluated other, nontechnical aspects of value to consumers, such as color and ease of use. The electric lamps tested are in the low-power range and are already in use in solar photovoltaic systems or have potential for such use (12 Volt, DC).

Three categories of lighting are relevant for solar photovoltaic systems or other direct current applications for households in developing countries: general lighting (illumination of a whole room), localized and task lighting (illumination of a part of a room such as a table), and orientation lighting (sufficient only to recognize shapes). Both the luminaire and the type of lamp determine overall lighting characteristics. Consumers can usually satisfy their lighting needs by buying an appropriate lamp with an appropriate luminaire. The total output of visible light (luminous flux) is one of the most important characteristics of a lamp. Conversion of fuels or electricity into visible light takes place in a number of different processes and under different conditions, resulting in a wide range of luminous efficacy. Electric lights are far more efficient than nonelectric lights. In the test they consumed 65 times less power, on average, at the same output level of visible light.

Table 1: Suitability of lights for different tasks

	General lighting	Localized and task lighting ¹	Orientation lighting
Fluorescent tubes with reflector	●●●	●●●	—
Fluorescent tubes without reflector	●●	●	—
Small incandescent lights	—	—	●
Halogen	—	●●●	—
Cluster-LED ²	—	●	—
Solar lanterns	●●	●●	●
Pressurized kerosene	●●●	●●●	—
Hurricane lamp	●●	●	●
Kerosene wick lamp	—	—	●
Gas lamp	●●	●●	—
Candle	—	—	●

●●● very suitable; ●● suitable; ● possible; — less suitable; — unsuitable.

1 Normally a distinction is made between localized (illumination of part of a room) and task lighting, but in the case of the relatively small rooms in which DC lighting is usually applied in developing countries, the distinction becomes unclear
 2 These conclusions are valid only for the specific type of cluster-LED which was tested which produce a narrowly focused beam of light.

The luminous flux of the lights in the test sample ranged from about 1 to 1,000 lumens for the electric lights and from 10 to 2,000 lumens for the nonelectric lamps. Power consumption ranged from less than 1 watt to 15 watts for the electric lights and from 60 watts (wax candle) to 1,400 watts for the nonelectric lights (petromax). For both types of lamps, the range in the levels of luminous efficacy was very wide: from 1.7 to 60 lumens per watt for electric lamps; and from about 0.1 to 1.4 lumens per watt for nonelectric lamps. Different combinations of (electronic) ballasts and lamps (tubes) produced significant variations and purchasers have no way of knowing what they are getting when they purchase.

Standards for Light Fixtures

There are neither international standards for solar photovoltaic systems nor for their individual components. In formulating lighting standards, it is important to focus not just on the lumen output, but also on color, ease of use, availability, lifetime, tube blackening, and, in particular, cost, as these aspects are important to consumers. Lighting standards that may be adopted should:

- Set a minimum luminous efficacy, taking into account the effects of color
- Apply only to the luminous efficacy of general lighting (power consumption of about 4 watts or more), not to orientation lighting
- Include a maximum power level for orientation lights
- Have different luminous efficacy standards for lamps or luminaires with and without a reflector.

Minimum quality norms can be proposed based on the laboratory tests. The laboratory measurements of 36 lamps yielded a range of luminous efficacy of 25 to 47 lumens per watt. Fluorescent lights without a reflector averaged 37 lumens per watt. The empirical number of 37 lumens per watt should therefore be used as the standard for compact fluorescent (CFL) lamps without a reflector and for fluorescent tubes without any fixture. The tests showed that a fluorescent tube mounted on a fixture but without a reflector has a luminous flux about 5-10 percent lower than that of a tube without any fixture. The proposed standard for fluorescent tubes without a reflector is therefore 35 lumens per watt.

An Indonesian manufactured fluorescent light.



NEW DEVELOPMENTS

Recent developments in LED (light emitting diode) lamp technology have enhanced their market potential as low cost, high efficient lamps. LEDs have only very recently been introduced to the general public for lighting purposes. Until late 1997, broad spectrum white-light LEDs were not even available. The cluster LED that was tested had a fairly poor color rendering (it used a cluster of blue and red LEDs to produce an apparent white light). It also had a luminous distribution that was focused in a

beam with a small angle that produced high levels of illumination in one direction and much lower or no levels in the other directions. This cluster LED was not considered suitable for an orientation light in a solar home system, although it might be appropriate for solar-powered torches. More recent cluster LEDs can, however, be very suitable for orientation lights. For example, white light LEDs with very good color rendering (CRI>85) have become available since the tests took place. New tests most likely would show more positive results for LEDs than was the case in this test.

Assuming a typical value of 80 percent for the efficiency of a luminaire with a reflector, the proposed efficiency standard for luminaires with fluorescent tubes and a reflector is 30 lumens per watt. More detailed information about the test results will be available in a forthcoming ECN publication.

Implications for User Choice

For household applications in developing countries there are numerous lighting options covering a wide range of lumen output levels, energy consumption, and costs. But many technically feasible alternatives for household lighting are not commercially available in developing countries. Consumers in rural areas, in particular, have very few choices of lamps. One reason is that lamp manufacturers do not appreciate the potential of the rural lamp market and believe it is too small for more efficient low-wattage lights. Field surveys have demonstrated, to the contrary, that a wider spectrum of lights, particularly in the low power range (1-10 watts), would better meet the cost and quality criteria of many rural customers. This applies both for photovoltaic installations and for rechargeable (car) batteries.

In addition, consumers should be better informed about the different factors that should guide the purchase of a lamp. Better standards would improve consumers' access to good information; printing the information on the lamp's packaging would be better still. Above all, a larger range of lamps should be available in rural retail shops. Designs of solar home systems need to offer one or more low-cost, low-wattage lights for orientation lighting. When only orientation lighting is required, a low-efficiency, low-power (for example, 1 or 2 watts) incandescent light is better than a high-efficiency 6-watt light to meet both energy-efficiency and consumer preferences.

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