RURAL LIGHTING

Introduction

Lighting is taken for granted in industrial countries and in many urban areas of developing countries. It is hard for many people to imagine living at night without being able to obtain light at the flick of a switch. However, about half of humanity, over 2500 million people, live without much light after sunset, since they do not have access to grid-connected electricity.

Lighting in the rural areas of developing countries is generally provided by candles or kerosene lamps, while torches (or flash-lights) powered by expensive, throw-away dry-cells are used as a portable source of light for intermittent use.

Figure 1: A solar lantern being used in Nepal. Photo: Practical Action Nepal.

What is light?

Light is electromagnetic radiation; the human eye is sensitive to a spectrum with visible colours as seen in a rainbow. When these colours are mixed they appear as white light. More energy is present in the light of the upper or violet/blue end of the spectrum than at the red end. Therefore, more energy is generally necessary to produce the blue-violet component needed to produce what to the eye appears as white light. Therefore the quality of light (in colour terms) influences the energy requirement; if colour does not matter then it is at least theoretically more efficient to use a red or orange light, and this in fact is common practice in the case of street lighting where the most energy-efficient lights are used, namely orange/yellow sodium lights. Clearly, for domestic purposes there is merit in paying something extra to achieve a white, or near-white light.

Light intensity, or illuminating power of a light source in any one direction is commonly defined in candela, which although it has a rigorous scientific definition, for practical purposes can be thought of as 'candle-power'; i.e. the output from a standard paraffin-wax candle. The rate at which light is emitted is measured in lumens, which are defined as the rate of flow of light from a light source of one candela through a solid angle of one steradian. A more easily understood approximation of this would be to imagine a one candela candle at the apex of a conical lampshade with its sides sloping at about 70 degrees to each other; the conical beam emitted, diverging at about 70 degrees, would be about one lumen.

Methods of providing light

There are two main physical principles by which light may be produced:

- incandescent
- fluorescent

Practical Action, The Schumacher Centre for Technology and Development, Bourton on Dunsmore, Rugby, Warwickshire, CV23 9QZ, UK
T +44 (0)1926 634400 | **F** +44 (0)1926 634401 | **E** infoserv@practicalaction.org.uk | **W** www.practicalaction.org

technical brief

The incandescent principle depends on heating a source to a temperature in the region of 2000, 4000 or 6000°C to obtain reddish, yellowish or white light, respectively. Typical examples are candles and lamps utilising a bright flame (where white hot or incandescent particles of carbon in the flame produce the light) and incandescent filament light bulbs where a fine coil of tungsten wire is heated (in a vacuum or inert low pressure gas to prevent the filament oxidising or burning) by an electric current passing through it. All incandescent light sources, whether flames or electrically heated filaments, tend to produce more heat than light and are therefore relatively inefficient in the rate of conversion of energy to light.

Fluorescence occurs under certain conditions when a material can be made to glow with a 'cold light'. Fluorescence is a phenomenon in which the atoms of a gas, vapour or solid are excited in such a way that they emit light. In some cases such as sodium and mercury vapour discharge lamps (used commonly for street lighting) vapour in a glass tube emits the light. In other cases such as the commonly used fluorescent tube lights, ultraviolet light, which is invisible to the eye, is emitted by exciting mercury vapour atoms within the tube, and this in turn causes a white translucent coating in the tube to fluoresce with a whitish light.

Figure 2: Shirantha Lamal studying by a biogas powered lamp in Bandarawella, Sri Lanka. Biogas is piped directly into the home and is used for cooking and lighting. Photo: Practical Action / Zul.

In other words, the coating converts invisible ultraviolet light into visible white (or near-white) light. Most fluorescent processes involve some expenditure of electrical energy, so they are accompanied by the production of some heat. (Non-electrical fluorescence is used where the mantles of pressure lamps and gas lamps are heated and emit a much brighter and whiter light than would occur simply as a result of their temperature.) For practical purposes, the options for lighting reduce generally either to lamps that run on fuels, or electric lights. Table 1 indicates the options and their relative lighting capability.

Type of light	Energy source	Intensity (lumens)	Efficiency (lumen/W)
Candle	Paraffin wax	1	.01
Oil lamp (wick)	Kerosene	1-10	.01-.1
Hurricane lamp (wick)	Kerosene	10-100	.1-.2
Oil lamp (mantle)	Kerosene	1000	1
Gas lamp (mantle)	1.p.g (eg butane or biogas)	1000	1
White Light Emitting Diode 1W	Electricity	25 - 50	25 - 50
Filament lamp 3W	Electricity	10	3
Filament lamp 40W	Electricity	400	10
Filament lamp 100W	Electricity	1300	13
Fluorescent 15W	Electricity	600	40

Fluorescent 30W	Electricity	1500	50
Mercury 80W	Electricity	3200	40
Sodium sox 35W	Electricity	4500	128

Table 1: Lighting capacity

More important to the user than the efficiency in lumen/watt is the cost per lumen. Kerosene and candle wax are cheaper sources of watts than any form of electricity, and this partially makes up for their inefficiency, but not for their poor quality light (wicks) or the amount of heat. Kerosene lamps produce better light, but they are unpleasantly noisy and uncomfortably hot to be near in a tropical climate; they also use much more fuel than wick lamps, and are troublesome to start. Cylinder gas lights provide a slightly more expensive but convenient alternative.

All combustion lamps pose a real fire risk. Kerosene and butane are also becoming increasingly expensive and are sometimes in short supply in developing countries.

Therefore the rest of the technical brief addresses the use of electric lighting in rural 'off-grid' locations.

Electrical lighting in rural areas

Solar Lanterns

Solar lanterns are an all in one system that houses the battery storage and controls along with the lighting unit. They are easy to use and do not require any installation.

Practical Action (then ITDG) formed a partnership with Sollatek, a UK based company who specialise in solar and electronics manufacture, to develop two versions of a robust solar lantern called the Glowstar and the Glowstar plus. Sollatek has distribution outlets in over 25 countries.

Figure 3: A solar lantern used within a workshop making stoves, Kenya. Photo: Practical Action.

Sollatek UK Limited
Unit 4/5 Trident Industrial Estate
Blackthorne Road
Slough SL3 0AX
Tel: +44 1753 688300
Email: sales@sollatek.com
http://www.glowstar.net/

Light up the World promote appropriate small-tech, system of providing lighting to poor rural communities using White Light Emitting Diodes (WLED). These diodes consumes less than one tenth of a Watt and has a continuous life of over ten years. The Light up the World project in Nepal used simple hand powered generators to power the low energy lighting systems in remote parts of the country. The projects is described on page 14 of Boiling Point Number 45.

Light up the World
University of Calgary, Mechanical Engineering
1111 22nd Ave NW
Calgary
Alberta
T2M 1P6, Canada
Tel: +1 (403)284-2596
Website: www.lightuptheworld.org

Lighting systems
Low cost systems that require a small amount of electricity usually from a renewable energy source and using florescent lighting can be installed into many locations. They sometimes are provided in kit form and are linked to a mini grid or are linked to their own energy supply such as a wind turbine or solar panel.

Storing electricity
Electrical storage in the form of a battery will be required. It is possible to use disposable batteries (ie dry cells) which are bought ready charged and thrown away when exhausted. These are convenient to use but extremely expensive in terms of electrical energy costs and need to be transported and distribution to rural areas raising the cost even more. There is also an issue of waste disposal once they are finished with.

Rechargeable batteries, are more cost-effective than disposable batteries, but recharge equipment then becomes necessary. The two main options available are

- nickel-cadmium batteries
- lead-acid

Nickel-cadmium batteries are generally less widely available (except as dry-cell substitutes) and cost more, but they can be more robust and tolerant of abuse than lead-acid batteries. However they self-discharge quite quickly if not used. Electrical energy from a lead-acid battery can cost as little as one twentieth to one fifth as much for the same amount of energy delivered from primary (dry) batteries.

Lead-acid are similar to the batteries used in cars and in many cases car batteries are used in lighting systems as these are the most widely available type of battery. For most lighting purposes these are the easiest and cheapest option. They are also available as deep-discharge batteries which have a longer life than car batteries, and if looked after tend to be better for general electrical storage.

Most lead-acid and nickel-cadmium batteries require regular checking of their electrolyte level and topping up with distilled or deionised water, (not with acid). Rain water can be used for this purpose, providing it has not been contaminated in any way. Low maintenance and maintenance-free lead-acid batteries are also available, at slightly increased cost.

An important point to note with lead-acid batteries is that their life is considerably shortened if they are over-discharged. Ideally they should only be discharged to about 50% of their full rating; ie a 60Ah (ampere-hour) battery should only be discharged to 30Ah before recharging it.

Typical present deep-discharge load-acid battery costs are in the region of £60/kWh of total rated capacity or £120/kWh of usable storage, while nickel-cadmium will be about three times this level. The cost increases with some specialist types and very small batteries.

Batteries are generally provided with nominal voltages in multiples of 2V; common larger capacity lead-acid batteries will be 12V or 24V nominal voltage.

Cable runs should be kept as short as possible with low voltage supplies, (or very heavy cable must be used) otherwise significant losses will occur in the cables. A 1.2V voltage drop in a 12V system represents a loss of 10% of the power transmitted down the cable. The voltage drop is numerically equal to the current in amps times the resistance of the cable in ohms; $1mm^2$ copper cable will have a voltage drop of 0.025A, so 10m of $1mm^2$ cable carrying 1.25A will have a voltage drop of 1.25 x 0.042 x 10 = 0.525V. This represents about 96% cable efficiency, which is acceptable. However, 100m of the same cable will cause a voltage drop of 5.25V which will cause the light not to work and in any case represents a quite unacceptable loss of nearly 50% of the energy supplied.

A 30W fluorescent light (for example) running off a battery with an inverter for six hours per night will consume 180Wh each 24 hours. Losses in the inverter, cables and the battery will increase this requirement to about 300Wh/24h. To avoid more than 50% discharge and provide a nominal 24 hours storage capacity would require, with the above example, a battery with a usable capacity of 600Wh (1200Wh to total discharge), costing in the region of £80.

The energy sources
The main methods by which the electricity for charging may be provided:

- taking the battery to the nearest mains supply and putting it on charge
- using a small engine-powered generating set
- using renewable energy such as photovoltaic or wind charging systems
- using a hybrid system

Using a generating set imposes considerable problems as, unless power is being generated for other purposes too, the charging current, which is acceptable for small battery storage for just one or two lights is rather low for even the smallest generating sets; hence the engine needs to be run at part load which results in inefficient fuel use and is bad for the engine.

A photovoltaic system is often the most applicable stand alone option, as adequate sun for charging can be found in most parts of the world, and such a system, apart from occasional cleaning of the array, requires little attention.

The main drawback is that solar photovoltaic arrays are expensive currently cost (delivered and installed) in the region of £3-5/Wp (peak Watt), The supplier should be able to advise on the size needed (and can generally supply a battery and lighting system too).

To run a 30W light for six hours would typically require, in a sunny tropical location, two nominal 40W solar modules, and would therefore cost in the region of £400. Areas with extended cloudy periods may need up to twice this capacity.

Another option is to use a small wind generator; this will generally be cheaper than solar power in locations having mean windspeeds above 4.0m/s in the least windy months. A separate technical brief gives further information on wind generators and gives a rule of thumb that the required rotor area of the wind generator for small-scale applications like lighting will be:

$$\text{Rotor area } (m^2) = \frac{\text{Energy demand (kWh/day)}}{0.0048\ V^3}$$

Where V is the mean windspeed in the least windy month of the year. For the 30W lamp for six hours example, it follows that a $0.5m^2$ rotor wind generator will suffice at 5m/s, a $1m^2$ rotor is needed at 4m/s and a $2.3m^3$ rotor at 3m/s. The typical cost of wind generators is around £400-600/m^2 for small machines (installed).

In our example of a 30W fluorescent light, which is comparable in illuminating power to a 100W tungsten filament lamp and brighter than a pressure kerosene lantern with a mantle, in a rural 'off-grid' location using wind or solar power, we will need the following items:

Item	Approximate cost
12V 30W fluorescent light with built-in inverter unit	£ 10
10m cable, connectors, etc	£ 10
1200Wh battery (rated) giving 6000Wh usable capacity	£ 80
plus either:	
60-90W (rated) solar array with battery charge regulator (depending on solar irradiation)	£200-500
or	

0.5 to 2m^2 rotor area wind generator with battery charge regulator	£200-900

This may sound a lot to pay for a single light, but the running costs will be negligible and good quality light will be reliably available. A pressure lantern, which is much less satisfactory, would cost only about £15-30, but it would consume in the region of 5 litres of kerosene per week on the same duty cycle which would cost typically £75-150 per year. The price of solar panels and small wind generators is declining in real terms as production increases, while the price of kerosene will continue to rise. There are tens of thousands of small photovoltaic lighting systems in use in developing countries and tens of thousands of wind-powered lighting systems, particularly in China.

To over come the problems associated with the high initial costs of renewable energy systems for low income households in developing countries, financing schemes are often set up where the user can pay for the equipment in installments or rent the equipment off the supplier. A photovoltaic system can cost quite a lot of money and spare parts may be difficult to get hold of in a rural situation.

Further information

- *Energy for Rural Communities* Practical Action Technical Brief
- *Batteries* Practical Action Technical Brief
- *Wind for Electricity Generation* Practical Action Technical Brief
- *Solar Photovoltaic Energy* Practical Action Technical Brief
- *Kerosene and Liquid Petroleum Gas (LPG)* Practical Action Technical Brief
- *Rural Lighting: A guide for development workers* Jean-Paul Louineau, Modibo Dicko, Peter Fraenkel, Roy Barlow & Varis Bokalders*,* ITDG Publishing, 1994

Useful contacts

Light up the World
University of Calgary, Mechanical Engineering
1111 22nd Ave NW
Calgary
Alberta
T2M 1P6
Canada
Tel: +1 (403)284-2596
Website: www.lightuptheworld.org

Winrock International India (WII)
http://www.winrockindia.org
Winrock International (WI)
http://www.winrock.org
Winrock has developed a solar lantern for India.

Lights for Leaning
69 High Street, Cricklade, Wiltshire SN6 6DA
United Kingdom
Tel +44 (0)1793 750844
info@lightsforlearning.org
www.lightsforlearning.org
LED lighting systems for educational projects in Africa.

SolarAid
Bunhill Fields Meeting House
Quaker Court, Banner Street
London
EC1Y 8QQ
United kingdom
Tel +44 (0)20 7490 3321
Fax: +44 (0)20 7490 3321
E-mail: info@solar-aid.org
Website: http://solar-aid.org/
Developed a solar LED lantern kit to fit kerosene lamps. This project is focused on Malawi.

Equipment suppliers

NEST - Noble Energy Solar Technologies Ltd.
A-9, Aero View Towers, Shamlal Buildings
Begumpet, Hyderabad - 500 016
India
Tel: +91-040 - 2776 2559
Fax: +91-040 - 2776 7062
E-mail: dtbarki@usa.net / info@solarnest.net
http://www.solarnest.net/html/
http://www.handsontv.info/series6/04_Energy Matters_reports/report1.html
Manufacture and sell solar lanterns and other solar equipment.

SolarElectro Co.Ltd.
Werner Consult
Büchner Str. 30
CH 8006 Zürich
Switzerland
Tel/Fax 0041-43-233 96 85
E-mail: wernerconsult@bluewin.ch
Suppliers of LED lamps with solar panels

The Freeplay Foundation
56 - 58 Conduit Street
London W1S 2YZ
United Kingdom
Tel: +44 0207 8512616
Fax: +44 20 7851 2675
contact@freeplayfoundation.org.
http://www.freeplayfoundation.org/
Indigo self sufficient wind-up LED Lantern using the freeplay windup technology to power an LED lamp. It has adjustable brightness and can run for 3 hours with 60 seconds winding at its lowest setting. Up to 70 hours on a full charge with night light setting or 2 ¾ hours on bright setting. Freeplay also produce a foot powered generator.

Practical Action
The Schumacher Centre for Technology and Development
Bourton-on-Dunsmore
Rugby, Warwickshire, CV23 9QZ
United Kingdom
Tel: +44 (0)1926 634400
Fax: +44 (0)1926 634401
E-mail: inforserv@practicalaction.org.uk
Website: http://practicalaction.org/practicalanswers/