# Lighting the world with LEDs

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## Abstract

Light Emitting Diodes (LEDs) present an opportunity to improve public health and to provide low-cost lighting to villages while significantly reducing $CO_2$ emissions, petroleum fuel consumption, and hazardous waste. Lighting accounts for approximately 19% of the world's greenhouse gas emissions and widespread use of LED lighting would significantly reduce this. Aspects of LED technology, the use of LED in lighting the developing world, and means of rapidly deploying the technology in an affordable manner are discussed.
*Keywords: LED lighting, public health, appropriate technology, energy conservation.*

## 1 Introduction

The world's population of 6 billion is expected to expand to 9 billion in the next 40 years [1]. In the absence of apocalyptic population reduction or a political will to reduce population growth the additional 3 billion people will have to be fed, clothed, housed, educated and provided with gainful employment. The consequences of this increase in population will be significant increases in resource use, particularly energy, whose availability underlies the technological and life-style advances of the last 3 centuries [2]. However, an increase in energy, using existing technology, will result in increased greenhouse gas emissions, which may impact on already stressed populations through climate change.

Predictions of the problems of resource availability for the future of humanity are not new. The predictions of Malthus [3] and the Club of Rome [4] were addressed by technology development [5], which increased the availability and

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security of food supplies, accessed energy resources in previously unavailable situations, and housed people in ever increasing clusters of high population density. These developments have required increased per capita energy consumption.

There are several sources of energy that do not significantly impact on the environment, but supply is only half of the solution of managing the impact of energy use. The other part of the solution is to provide increased efficiency in energy use. Significantly reducing the per-capita demand for energy may meet the energy demands of increased population growth without increasing energy production. There are many national energy efficiency programs [6, 7]. Yet it has to be noted that a 50% increase in population requires a 33% improvement in energy efficiency to maintain today's level of energy consumption per capita, and this does not allow for improving life-styles in the majority of the world that has the lowest per capita energy consumption, i.e. the developing economies. Energy efficiency savings will not be similar across all sectors of the economy, or all nations of the world, but the hope is that there will be a net decrease in per capita energy use. The most likely positive scenario to meet the future energy needs will be a combination of energy efficiency and energy production that has low impact on the environment in order to obtain the necessary target of providing energy for all without sacrificing the planet.

This paper addresses the issue of providing cheap low-cost lighting to communities while addressing the energy consumption issue at the same time. The technology based around Light Emitting Diodes (LEDs) provides the opportunity of improving energy efficiency (in this case watts per lumens) which, when combined with PhotoVoltaic power generation, also provides the opportunity for alternative energy sources to be implemented to provide the power. The issue of ensuring the rapid uptake of this technology in an environment of poverty, low-technology training, and lack of familiarity with the technology is also addressed.

## 2 LEDs and energy efficiency

An LED is a PN junction semi conductor diode that emits monochromatic light as electrons, which move from the anode (p-side) to cathode (n-side), fall into a lower energy state and release energy. The wavelength of the light depends on the gap energy of the p-n junction. Light emitting diodes are not a new technology, by the standards of the rapid development in technology of the last 50 years [8], but there have been significant improvements in the last 20 years that are now available in the market place. These developments are part of continuing technological improvement, and research in a number of places around the world is improving the cost of production, efficiency and capacity of LEDs [9, 10].

It is estimated that 19% of the world's energy is used for lighting: equivalent to the energy required for all transport and in equivalent greenhouse gas emissions equal to that produced from domesticated animals [11]. So the potential for energy and greenhouse gas emission savings is significant [12, 13].

At this stage LEDs are the most efficient light production system in terms of lumens per watt, having overtaken CFLs, and are still improving at a significant rate [14, 15].

Compact Fluorescent Lights (CFLs) are now widely used in domestic, commercial and industrial circumstances. They are very efficient compared with the incandescent lights and have much longer design lives, but have an environmental issue of mercury contamination, which neither discarded incandescent lights nor LED lights have. This contamination issue is well recognised, but is being rationalised against savings in energy. The savings in energy compensate the release of mercury in coal-fired powered stations. A CFL light may have 5-15mg of mercury (Hg) while a tonne of coal can release 0.1g of Hg or more [16].

LEDs do not pose a significant environmental problem, and have longer design lives and energy efficiency than CFLs. Short-term costs may be higher, but long term savings are significant. Their reduced power consumption results in a reduction of Hg production at power stations.

The price of LEDs is higher than CFLs and much higher than incandescent lights, but when maintenance and longevity are considered, are significantly cheaper. LEDs have design lives of 20 years, and can last much longer than this, though at a slowly decreasing level of luminosity per watt [17].

The significant decrease in the power demand (Watts) of LED-based lighting per lumen and their reducing cost now means that battery-LED lantern systems with inbuilt solar recharges are affordable. Such system are suited for the majority of people who are forced to use alternative lighting systems because they are in areas not connected to the national power grids or have unreliable power supplies (presently estimated at 25-50% of the world's population [18]).

An issue with PV-based rechargeable LED lanterns in terms of future breakthroughs lies in the area of battery technology. PV and LED systems have design lives of approximately 20 years, and are known to continue to work after this time, albeit with reduced efficiency. The cheapest battery systems are lead-acid systems, which are recyclable, but have design lives of 3 to 5 years, depending on the power drain regime, recharge cycles and quality. Clearly there would be great advantage in having a battery system whose design life was the same as the LED and PV systems, as all could be recycled at the one time. Work on battery technology is progressing the design life and power of batteries [19], but is not yet in the range of the PV and LED systems. New battery systems will have to be price competitive with lead-acid batteries, which are also being improved all the time.

## 3 Examples of LED lighting systems and alternative power

LED lighting systems are now widely used. LED-powered lights are used in camping lights, helmet lights, torches, industries of various types, and community lighting projects. Some of these will be briefly discussed in the following.

Probably one of the most ambitious projects in the world is to provide LED lanterns to the communities of the developing world, as ably illustrated in India [20,21] and Africa [22]. For most villages in India the kerosene lantern has been the standard source of light for many years but they present serious health and risk hazards associated with kerosene fumes and fire. In addition the luminosity is relatively low (10-20 lumins [23]). In many countries the kerosene has to be imported, so there is a significant drain on national budgets, not only in foreign exchange but through the subsidy programs that often apply to support the poor [24–27]. It is estimated that families use approximately 100L of kerosene per year and the subsidy at Rs8-9 per L is estimated at Rs340billion in India The indirect costs of poor lighting on eyesight, education, business and community activity probably dwarfs the direct cost.

Figure 1: LED lanterns without solar power attachments (photo courtesy MIC Electronics).

LED lanterns that can be solar powered are now cost-effective, can be demonstrated to recover purchase and maintenance costs in terms of savings on kerosene purchases over a period of 2 to 5 years (depending on national kerosene prices). Solar power recharging can be achieved by fixing a PV panel to a lantern unit or through village (community based) recharging stations, which provide the recharging service for very small cost. The later saves on the cost of the lanterns. Battery recycling systems are also needed at the village and district level, as are servicing facilities.

Indian railways have commenced the process of converting to LED lighting across their stations and rolling stock. A variety of facilities are being provided, from LED reading lamps in carriages to LED lights for stations.

LED street lighting is an exciting opportunity to reduce power consumption and provide communities with security. LED street lights, with and without solar power, are being roll-out in several cities in India. Rather than abandon existing infrastructure LED lights are replacing existing street lights, thus achieving an increase in luminosity while reducing power costs. For green-field sites the opportunity to install solar powered lights, supplied with the poles, is obvious. The reduction in cost in installation is also associated with not having to provide external power to each light. Self-contained solar-recharging LED street lights are an obvious choice in areas subject to natural hazards that may suffer cuts to power supplies. While there is no guarantee that any particular pole and light might survive a hazard, it is likely that enough will survive to provide lighting at the critical times of relief and recovery.

Figure 2: Examples of PV powered LED street lights in India (photo courtesy MIC Electronics).

## 4 Lighting the World

While the technology is available, distributing LED-lighting technology is another matter. The urgency for savings in the consumption of petroleum products, improved health, and reduced greenhouse gas emissions is obvious. The Indian government, and others, are committed to distributing the technology as soon as possible. Recent improvements in efficiency and reduction in costs have made distribution more financially feasible in developing economies, as well as developed economies.

Distribution is part of the story. There needs to be mechanisms for maintenance, recycling and recharging when PV facilities are not sold with each lighting unit. In addition, rapid roll-out requires financial management to enable communities and individuals to access the technology. Finally, the need for the technology is so great that manufacturing and distribution networks are also required.

For communities, as in the case of street lighting, BOOT schemes (Build-Own-Operate-Transfer) are viable options, as long as financial backing is provided. It should be noted that LED-based street lighting using PV generating systems is ideally suited to areas where rapid roll-out of lighting is required. A refugee camp could have a kilometre of street lighting (one light every 20 metres, offset on opposite sites of the street = 500 lights) in a matter of a week given access to the site and landing of equipment and work teams. A health compound could be provided with light in a day. Small scale PV generators could also provide light within the buildings and this could be installed in a day. The advantages in savings on fuel cartage for conventional diesel powered generators are obvious.

For families and individuals the conversion from kerosene lanterns to PV recharged LED lanterns could take place rapidly provided funding for the technological transition is provided in the form of loans. Micro-financing systems [28] are ideally suited to this, as the loans could be repaid from the savings on kerosene purchases. PV recharge stations would provide employment at the village and district level, as would recycling and financial management systems based around the micro-finance. Capital for the micro-finance could be derived from several sources, including direct government support as well as donor support. The advantage of microfinancing is that the capital injection is repaid within a matter of years, and the small profit margin on the sale of the goods finances the microfinance structure and, if care is taken with maintenance contracts, the maintenance and recycling of systems.

## 5 Conclusions

The rollout of LED lighting, replacing both incandescent and CFL lighting, should bring about considerable savings in energy use per capita, provide improved lighting to people at the bottom of the pyramid, who comprise the majority of the world's population, reduce per capita greenhouse gas emissions, and stimulate employment and training.

The rollout will have to happen in a micro-finance environment in order to maximise benefits of transferring to the new technology and to bring about the transference in the minimum possible time.

A number of countries are already aggressively pursing the transformation, and coupled with photovoltaic power generation, should bring significant commercial, health and educational benefits to their people.

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