LIGHTING

Energy efficient lighting for sustainable development

www.wisions.net

WISIONS of sustainability

CONTENTS

WISIONS INITIATIVE

WISIONS of sustainability is a Wuppertal Institute initiative that is supported by the Swiss-based foundation ProEvolution. The initiative was launched in 2004 to promote practical and sustainable energy projects – particularly those in developing countries.

As well as the Technology Radar, which serves as an information tool, practical financial support for the implementation of innovative and feasible energy projects is provided via SEPS – Sustainable Energy Project Support. To date more than 50 projects around the world have been selected for SEPS support.

WISIONS TECHNOLOGY RADAR

The aim of the WISIONS Technology Radar is to give a comprehensive and transparent overview of the existing renewable energy technologies and their possible contribution to meeting basic energy needs. It serves as a scientifically based source of information on solutions for addressing the global challenges related to the need for energy.

Key questions addressed for each technology refer to the technology's potential contribution to global sustainable development and its potential to achieve the Millennium Development Goals. In addition, the environmental, social and regional impacts that are linked to the implementation of the technology are examined. Where possible, development options for the future are also analysed, as well as an appraisal of the necessary framework for ensuring that the technology is economically viable.

This, the third brochure, summarises key findings on technical options for meeting diverse everyday lighting needs by the rational use of energy. More data, examples and information are available on our internet platform, www.wisions.net, under the heading 'Lighting'.

SEPS CASE STUDIES

Case studies, supported by SEPS – Sustainable Energy Project Support – illustrate the practical implementation and lessons learned in the field. In addition to examining the technical and economic viability of the projects, environmental and social aspects are highlighted. Some successful examples of these projects are described in this publication and also feature on our website, www.wisions.net.

LIGHTING

ENERGY EFFICIENT LIGHTING FOR SUSTAINABLE DEVELOPMENT

Lighting plays a key role in our daily lives as well as in commerce and industry worldwide. It makes it possible to carry out activities at night, or where natural light is not available. Supplying 'artificial' light consumes energy and, globally, electric lamps are the most common source of artificial light. However, fuel-based technologies (such as kerosene lamps) are also widely used, particularly in regions without access to the electricity grid or with an unreliable electricity supply.

Current lighting solutions present crucial challenges for both local and global sustainable development. Some notable examples are:

- At present, grid-based electric lighting consumes 19% of total global electricity production. This represent approximately 0.7% of global GDP and 7% of global energy-related CO_2 emissions [3].
- Fuel-based lighting (e.g. paraffin or kerosene lamps) represents only 1% of global lighting. However, it is responsible for about 20% of lighting emissions and consumes approximately 3% of the world's oil supply [2].
- The costs of kerosene and non-rechargeable batteries may account for more than one third of the total income of the poor.
- The most popular fuel-based technologies provide extremely low quality light. Their use also carries high risk of injury (i.e. burning) [1].

A wide range of energy efficient lighting technologies exists. This publication aims to give a clear overview of those alternatives, as well as discussing the difficulty of consolidating the alternatives as 'common sense' solutions. The main ideas are also illustrated through the experiences from projects implemented in different developing and emerging countries.

WHAT IS ENERGY EFFICIENT LIGHTING?

Energy efficiency refers to the amount of energy required to provide appropriate light. The specific requirements of a lighting system depend on the type of tasks to be accomplished in a particular space.

Defining a specific lighting need is a rather complex task. It involves not only the measuring of (technical) parameters (e.g. illuminance, contrast, colour, temperature, etc.), but it is also influenced by subjective perceptions, which vary from region to region, or even from person to person.

For the purpose of the Technology Radar, different everyday lighting needs can be broadly classified into three groups, according to the types of spaces where light is required:

1. Domestic lighting.
2. Lighting the workplace (i.e. options for commercial and institutional buildings).
3. Lighting outdoor spaces.

There are undoubtedly numerous different specific lighting cases valid for each group. However, for each of these 'lighting need groups' it is possible to identify the conventional inefficient lighting technologies that are predominantly used. The search for superior options involves examining the different technical options available and comparing their energy demand.

MUCH MORE THAN A LAMP

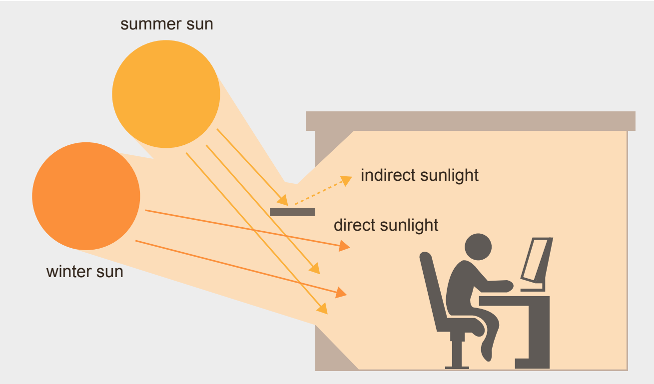
Lamps are sources of artificial light and, therefore, are central elements of any lighting system. In most cases, however, both the quality of light and energy efficiency can be significantly improved by the correct selection of other 'auxiliary' elements of the system.

The most common perception sees the lamp as the device required to fulfil our lighting needs. However, when looking for more energy efficient ways to meet our needs, it is preferable to think in terms of **lighting systems**, i.e. a set of elements, which, by combining different functions and properties, provides appropriate artificial light and avoids unnecessary energy losses.

The Technology Radar classifies the components that can make up an energy efficient lighting system into five groups:

- Components for improving the use of daylight
- Lighting controls
- Ballasts
- Luminaries
- Electric Lamps

Components (or measures) for improving the use of daylight

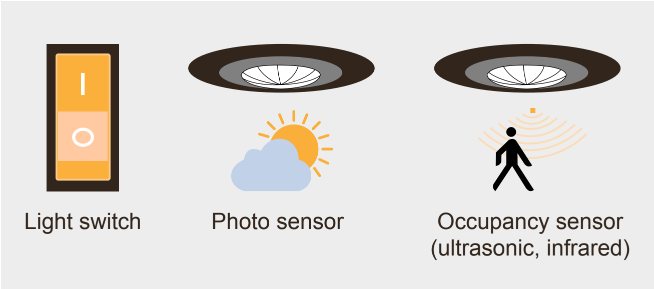


Daylight is probably the most "energy efficient" lighting option. It seems also to have positive effects on health and productivity [2]. However, harnessing natural daylight for lighting indoor spaces can be a complex task. Some of the major issues that should be considered are outlined below.

- The availability of daylight is constrained by the design of buildings. Issues such as the availability and orientation of windows, the floor-to-ceiling height and the layout of the rooms influence the ingress of daylight as well as the options for distributing it within the building.
- Allowing the use of daylight can conflict with other energy-related services such as the need for heating and/or cooling rooms. In hot climates or seasons, daylight can translate into an additional source of (unwanted) heat, while in cold climates or seasons windows can lead to significant losses of (appreciated) heat.
- Allowing daylight into a room can make the light quality worse by creating glare.

A number of different types of measures and components can help to increase the use of natural daylight: from the (rather simple) use of translucent ceiling panels to the installation of control systems that respond to daylight and occupancy, the use of special louvers and glazing materials and even the application of specialised software to optimise building design to take better advantage of natural daylight.

Lighting controls



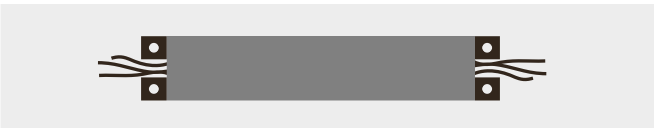
Lighting control technologies comprise a combination of devices and control strategies that allow for the provision of lighting services that can be varied in accordance with actual levels of natural daylight and the needs of the location.

Controlling the supply of artificial light can make significant energy and cost savings. This is true for almost any kind of scenario, from a single electric lamp to an entire lighting system in a building complex. Typical areas with energy saving potential:

- Illuminated rooms (e.g. bathrooms), corridors or stairways that are empty during long periods.
- Rooms or corridors with large windows or transparent walls where electric lights are continually on regardless of the supply of natural daylight.
- Passages between buildings or external corridors where electric lights are on even when there is sufficient natural daylight.
- Streetlights that operate at maximum levels even at off-peak times.

The most simple lighting control device is the conventional light switch. Providing users with the option to turn a lamp or sets of lamps on or off according to the required light levels can - in some cases - improve the energy efficiency of a whole system. Occupancy sensors and photo sensors are the most common options for automated control strategies.

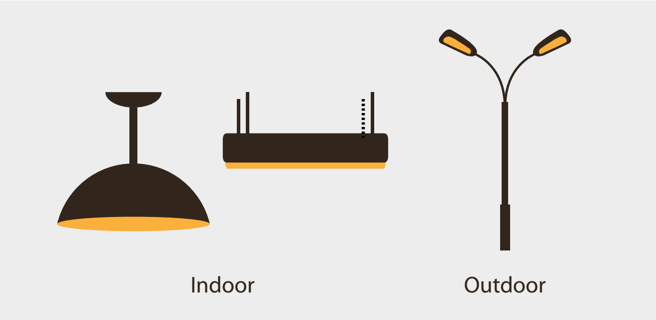
Ballasts



Ballasts are power regulation devices that are required by most electric lamps. The main function of electrical ballast is to ignite the lamp, limit the supply of electrical current, transform the voltage and correct the power factor.

In certain types of lamps, the ballast is already integrated into the commercial product, such as in the case of compact fluorescent lamps. However, for many applications (especially in lighting systems for commercial and institutional buildings as well as outdoor lighting) ballasts are commonly separate components. Appropriate ballast selection has a direct effect on the energy efficiency and light output quality of the whole lighting system, as well as on the life span of lamps.

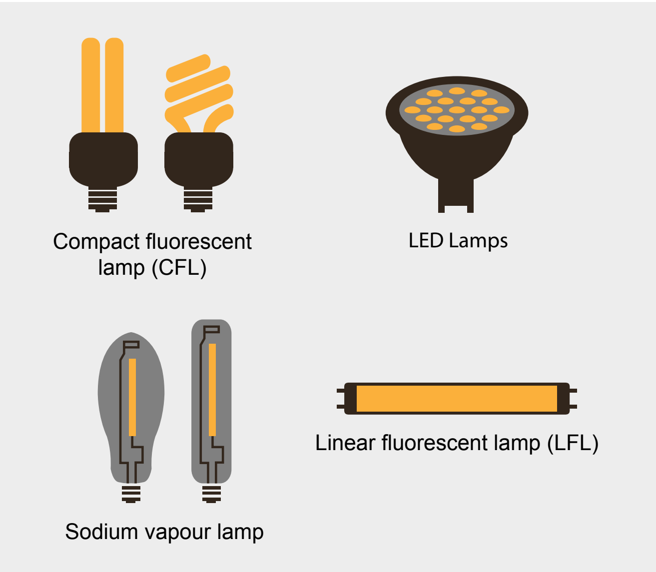
Luminaries



The luminaire (also known as the light fixture or fitting) is the frame to which lamps and other required components (such as ballasts, reflectors, lamp sockets etc.) are fixed. In addition to playing a structural and protective role, the luminaire plays an important part in the provision of efficient and high quality lighting.

The main task of the luminaire is to distribute, diffuse and direct the light emitted by one or more lamps. The luminaire consists of the housing, lamp sockets, reflectors and other components for the diffusion and distribution of the light, such as louvers or lenses.

Electric lamps



Electric lamps convert electric power into light. To achieve this result different physical principles can be applied but, in all cases, only a fraction of the electrical energy provided can be effectively transformed into light.

The ability of a lamp to effectively transform electrical energy into light is commonly measured by the 'luminous efficacy'. This parameter records the level of lumens (a measure of the light output of a lamp) per watt of power consumed. Hence, generally speaking, the higher the efficacy (lm/W) the lower the amount of energy required to provide the specific lighting service.

However, the actual energy demand for a lighting application can be significantly influenced by all other components of the lighting system. Therefore, the luminous efficacy of a lamp is a relevant indicator for energy efficiency, but often not the only indicator.

Additionally, other factors like lumen depreciation and the effect of temperature may also be important when comparing lighting options.

- Lumen depreciation: over time almost all lamp types experience a decrease in their light output.
- Effect of temperature: some types of lamps are particularly sensitive to temperature, meaning their light output varies widely with temperature changes.

THE SOCIO-ECONOMIC INERTIA

Highly energy efficient and smart lighting technologies are already globally available. Most of them have actually been on the market for decades. However, in many cases, conventional and less efficient alternatives are still preferred, even when superior technologies may offer similar or better technical and economic results.

The use of conventional technologies is entrenched in habit: from the consumer who buys a lamp to the architect who plans a building, the engineer who designs the lighting system for a building and the government bodies responsible for formulating building standards. Changing those common practices in order to integrate the use of more efficient alternatives has proved very difficult. The Technology Radar pays particular attention to these issues and gathers them under the subtitle 'social issues'.

LIGHTING AT HOME

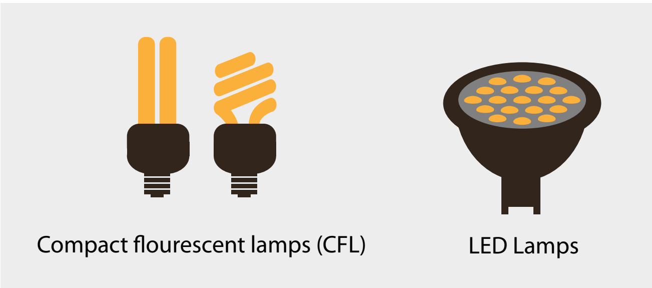
The provision of lighting is one of the most basic energy applications in the home. Lighting options for residential purposes can be roughly classified as electric and non-electric. In both cases, lighting accounts for a significant part of a household's energy consumption and is related to detrimental environmental and social impacts.

Two currently available technological options mean that significant improvements are possible in lighting quality, energy efficiency and even cost reductions relating to lighting our homes:

- Efficient lamps for domestic use
- Solar lanterns

The following sections describe the main features of these energy efficient alternatives, the related opportunities and risks and the specific challenges to the wide adoption of these technologies.

EFFICIENT CONSUMER LAMPS (CFL AND LED)



Residential lighting accounts for about 31% of global electricity consumption [2]. Inefficient lamps are still the preferred option in many countries, but more efficient consumer lamps, such as compact fluorescent lamps (CFLs) and products based on light emitting diodes (LEDs) could replace these. These alternative technologies use four to five time less energy than conventional bulbs and are commercially available in a variety of models.

Environmental Issues

By replacing inefficient incandescent bulbs, CFLs and LED lamps can mean energy savings of 80% or more and can decrease the levels of greenhouse gases (and other hazardous emissions) related to the provision of electric power. However, in order to mitigate the overall environmental effect of the widespread application of efficient lamps, the establishment of appropriate quality standards for their production, disposal (particularly at consumer level) and recycling is critical.

Potential negative impacts are associated with the production and disposal phases. In particular, the manufacture of electronic

components is characterised by significant resource consumption and the use of risky substances, like perfluorocarbons, that can produce high levels of greenhouse gas emissions. Both technologies (CFL and LED) contain a wide range of valuable materials that can be recycled but one current major concern relating to CFL technology is the emission of mercury, particularly during the disposal phase [4].

Social issues

The broad application of efficient lighting technologies promises to make an important contribution to more sustainable energy consumption. However, the social adoption of the technologies faces many challenges beyond the technical and financial ones. Some of the most relevant are outlined below.

- Awareness of the benefits

The use of efficient lamps often translates into significant savings in electricity costs. Analysed across its entire lifecycle, an efficient lamp is a very cost-effective investment (see the section Economic Issues). However, the market price for CFLs and LED lamps is still higher than for traditional less efficient bulbs and motivating consumers to use (i.e. to invest in) efficient technologies may require diverse and creative ways of communicating the long-term benefits.

- Access to proper and clear information

There is already a wide range of efficient lamps on the market. In order to make it easier for consumers to compare products and make their purchasing decisions, it appears to be essential to provide clear quality standards, as well as independent testing systems and effective communication strategies and advisory services for disseminating the relevant information. When confronted with relatively new technology (and often also with a rather confusing range of products), users require some help in understanding how to choose the best product for their needs. Consumers risk making the wrong purchasing decisions, which can have multiple effects, for example:

- Extra lamps may be necessary to meet the specific lighting need, which may reduce or even negate the financial benefit.

- Publicity about disappointed consumers may create a situation where the market loses confidence and is unwilling to adopt the technology.

- Awareness of environmental risks

Even in countries where efficient lamps already have a high share of the market, many consumers are not aware that the lamps should not be thrown away in the general waste. Clear information about the environmental risks and the need to make use of recycling systems should be widely communicated.

- Establishing proper recycling systems

Individual households are the main buyers of efficient lamps for domestic applications. Therefore, in addition to establishing appropriate recycling systems, effective strategies to encourage consumers to return their used bulbs to designated collection points are also crucial.

Development status and prospects

Since some governments, such as the European Union in 2009 and Brazil in 2005, started phasing out the use of incandescent light bulbs for general lighting, energy efficient lamps have been improved technologically and their market share has increased. Globally, more and more governments are introducing efficient lighting programmes and passing related bills, which will further promote the development of these technologies and their market penetration.

Economic issues

Efficient lamps are considerably more expensive to buy than traditional incandescent bulbs. CFLs are around four times more expensive and LED lamps can be as much as 20 times the cost (or more). However, when electricity and replacement costs are taken into account, incandescent bulbs prove to be the more expensive option.

By using a simple financial projection, Table 1 illustrates the advantage of investing in efficient lamps. The illustration assumes that a light source is used for 4 hours per day on an electricity tariff of 10 US cents per kWh. The total electricity costs for the first year are highlighted in the table. The example

Table 1.
Simple financial comparison between investing in efficient lamps and conventional light bulbs

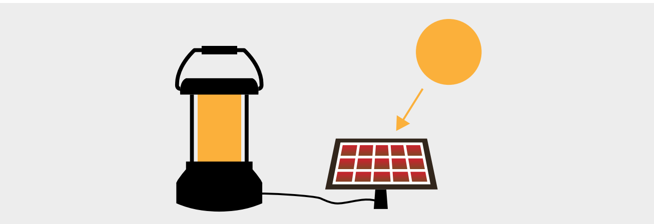
Description	Units	Incandescent bulb	Compact Fluorescent Lamp	LED Lamp
Lamp type	Watt	60	15	8
Price of lamp	US$	1.5	7	30
Lifespan	hours	1,000	10,000	20,000
Daily average use	hours	4	4	4
Electricity price	US$ per kWh	0.1	0.1	0.1
Yearly electricity costs per lamp	**US$ per lamp per year**	**8.76**	**2.19**	**1.17**
Replacements after 14 years	no. of lamps	20	2	1
Replacement costs in 14 years	US$	30	14	30
Total costs after 14 years	**US$**	**152**	**44**	**46**

demonstrates that running the inefficient incandescent bulb costs almost four times as much as the efficient CFL option (or eight times as much as a LED lamp).

To complete the analysis, the operational lifespan of the lamps (under identical conditions) should also be taken into consideration. While the LED lamp should last for around 14 years, the CFL would need replacing between the 6th and 7th year and the inefficient incandescent bulb would have to be replaced 20 times within the lifespan of one LED lamp. Adding these replacement costs to the electricity costs over the lifespan of a LED lamp (14 years), the example shows that using incandescent lamps is more than three times more expensive than any of the energy efficient options.

It is important to note that this simple analysis is only valid when assuming that the efficient lamp will be able to provide at least the same light quality as the traditional technology. As described above, comparing different kinds of lighting options is currently a difficult task.

SOLAR LANTERN



Solar lanterns are promising options for the provision of basic lighting services to off-grid populations. Light powered by electric sources – including solar photovoltaic - is more effective, cleaner and of better quality than light derived from any other source (e.g. candles or oil lamps or kerosene lamps).

Solar lanterns are made up of five major components:

1. Power source: commonly small photovoltaic modules (below 10W).
2. Power storage: rechargeable batteries.
3. Light source: commonly LED lamps or CFLs.
4. Lamp housing: two main functions influence the design of the lamp housing – the need for the lamp and other components to be mechanically protected and the requirement for the light to be distributed to best meet its purpose. Most solar lanterns are designed as portable devices.
5. Electronic controls: a control for charging and discharging batteries is crucial. Many solar products offer options for charging or powering other small electrical devices (such as mobile phones, radios and small fans). In such cases additional power controls may be necessary.

Environmental Issues

By replacing traditional kerosene lamps, the solar lantern offers a number of environmental improvements. Notable examples include the reduction of indoor air pollution and the contribution to climate change mitigation.

Solar lanterns do not produce toxic emissions during operation whereas kerosene combustion produces hazardous air pollution, often in enclosed spaces (e.g. in the home or in small business premises). The concentration of toxic particles can reach high levels and considerably increases the probability of the development of chronic bronchial diseases.

The operation of the solar lantern does not produce greenhouse gas emissions. From a lifecycle perspective, the production and distribution phases of the product are the major source of emissions. There appear to be few, if any, sound lifecycle assessments of the technology. However, the quality and effectiveness of light from solar lanterns is higher than that produced from conventional kerosene lamps and the energy and resource efficiency of the production processes of the relevant technologies (e.g. solar PV and LED lamps) is continually improving.

The disposal of solar lantern components may become a controversial issue. In particular, establishing appropriate systems for the collection of used batteries may be crucial in order to avoid negative environmental impacts and also to recover valuable (scarce) materials, thereby improving the overall resource efficiency of the technology.

Social Issues

It is anticipated that solar lanterns will become the preferred lighting solution in regions without access to electricity, or where the power supply is unreliable. Ensuring that appropriate products and services related to the technology reach the target population entails complex socio-economic challenges. Some of the major issues are outlined below.

- Setting financial mechanisms

Often the upfront costs of solar lanterns are greater than the consumer can afford. Financial mechanisms (e.g. leas-

ing contracts or micro-credits) specifically adapted to the socio-economic conditions of the off-grid population should be part of any attempt to promote the wider adoption of the technology.

- Building distribution and service networks

Populations that lack access to electricity traditionally also lack access to other infrastructure and services (e.g. roads and markets). Potential consumers are generally dispersed across rural regions rather than concentrated in urban or semi-urban centres. Building cost-efficient distribution and service networks to reach this population may require the involvement of various local players (e.g. distributors and small retailers). Establishing new local businesses along the supply chain may also necessitate special finance schemes.

- Establishing quality systems

The market for basic lighting products is very diverse. However, a considerable proportion of commercial products are of poor quality [5]. Consumer dissatisfaction and discredited products may damage the market's reputation. The enforcement of quality standards and certification, combined with improved consumer information, may help to avoid the wrong purchases being made (i.e. protect consumers from losing money they can ill-afford). This, in turn, may protect against potential damage to the solar lantern market.

Development status and prospects

Different concepts for solar lanterns are already penetrating the market for basic lighting solutions and the diversity of designs is still growing. A wide variety of products and business models are being developed in order to better respond to the requirements of users. However, assuring quality is still a crucial issue in order to further develop the technologies.

Technical tests carried out on behalf of the German Agency for International Cooperation discovered that most of the commercially available solar lanterns are of very low quality. A wide range of potential improvements have been identified e.g. the mechanical and electrical design, the actual light output of the products, the recharging control of batteries, the efficiency of the ballast for the lamps, more accurate product labelling (the technical data given is often "too optimistic") [5].

Users' expectations are very diverse. A striking example is the quality of light, which includes the light intensity and the size of the light cone i.e. whether it is for ambient lighting or is a more direct light for a specific task such as reading or weaving. Some users would prefer to have a switch and a (relatively) fixed lamp rather than a portable device. The option for additional functions (e.g. mobile phone charging, radios etc.) is perceived as particularly useful. Other features, such as the means to easily supervise the charging/discharging process of the battery or the ease of access to maintenance and repair services, may be crucial for ensuring the long-term adoption of solar lanterns [6].

Solar lanterns integrate components from technological fields that are still in a dynamic and innovative phase, such as solar photovoltaic, LED lamps and rechargeable batteries. It is anticipated that within the next few years the further development of these technologies will result in significant improvements in performance, as well as in cost reductions.

Economic Issues

The average manufacturing cost of portable lanterns is around $20. Cost reductions of 40% are expected in the next few years, leading to a manufacturing cost of $12 by 2015.

The market price for a solar lantern ranges from around $17 to over $120 [7]. The actual price for the consumer will decrease accordingly, but can be twice as high as the manufacturing costs, or even higher.

By providing an alternative to the use of kerosene lamps and other traditional lighting options such as candles, the investment in a solar lantern can translate into savings in terms of fuel for lighting. Taking into account the current average price of kerosene in Africa, the payback period for an investment in an average portable solar lantern is around eight months. Taking into consideration the predicted reduction in manufacturing costs and the positive development of the solar lantern market, set against the increase in kerosene prices, Lighting Africa estimates that the payback period could reduce to five months or less by 2015 [7].

CASE STUDY 1

VILLAGE MICRO-FACTORIES FOR AFFORDABLE LED-BASED HOUSEHOLD LIGHTING SYSTEMS

PROJECT'S AIM

To improve access to low cost lighting by working with rural-based entrepreneurs.

PROJECT DESCRIPTION

Over 500 million people in Sub Saharan Africa have no access to adequate lighting. Typical rural households use mainly kerosene to meet their lighting needs. In order to improve the current situation, the application of LED lighting technology, powered by solar energy, is a promising option. It can provide clean, low cost and better quality lighting for rural populations in developing countries. The main challenge, however, is to make these products accessible to the energy poor.

This project, implemented by CAMCO in the Kagera Region, NW Tanzania, sought to improve access to low cost LED lighting systems by establishing local micro-factories at village level. Local capacity is used for the assembly, installation and marketing of LED lighting systems that are suitable for rural households with no access to grid electricity. Green Energies LLC, a US-based solar company that manufactures products for the developing world, was the project partner for the technology and training aspects. The local partner involved in terms of community liaison was SCC-Vi Agro-forestry, which is running a long-term programme in the region to improve the livelihood of farmers. The project team identified existing local groups (micro-finance groups) as suitable local entrepreneurs. The first stage, which took place in July 2009, was to train a pilot group. After monitoring and evaluating the initial results, another six micro-factories were set up at the end of 2009. These are located throughout the project area (Karagwe district). Furthermore, a revolving fund was established to facilitate the bulk import of components via a regional centre. From this centre the raw materials and imported components are distributed to the micro-factories in the villages.

Location:
Kagera, NW Tanzania

Costs:
Total: € 44,715
WISIONS financial support: € 44,715

CO_2 Reduction:
36,300 kg CO_2/year

Partners Involved:
Camco Advisory (K) LTD
VI Tree Planting Foundation
(SCC-VI Agro-Forestry Eastern Afrika)
Green Energies LLC

Implementation Phase:
03/2009 - 07/2010

Webpages:
www.camcocleanenergy.com
www.greenenergiesllc.com

TECHNOLOGY, OPERATIONS AND MAINTENANCE

During the training sessions, the entrepreneurs learned how to assemble, install and maintain the lighting systems and were also trained in marketing techniques. Two products are manufactured in the micro-factories: the Taa Bora flashlight/reading light kit and the A3 lighting system kit for mounted room lighting. Both combine the use of local low-cost materials, such as empty water bottles (for the lampshade and battery case) and imported components (manufacturing toolkits). The latter consist of LED modules, small solar panels (1.25 W) and a battery package (2 AA batteries). The solar panel for the A3 lighting system is installed on the rooftop of the house, so that the batteries are charged during daylight hours. The A3 also provides an attachment enabling the user to play a small transistor radio and, recently, a separate option was developed consisting of a small adapter for charging mobile phones.

The components were designed to be light, simple and safe to use. For the assembly and installation of the final products only simple tools are used. By changing/manipulating the number of components applied, the product can be adapted to various needs and uses within a village home. The lights are produced locally and maintained directly by the local entrepreneurs.

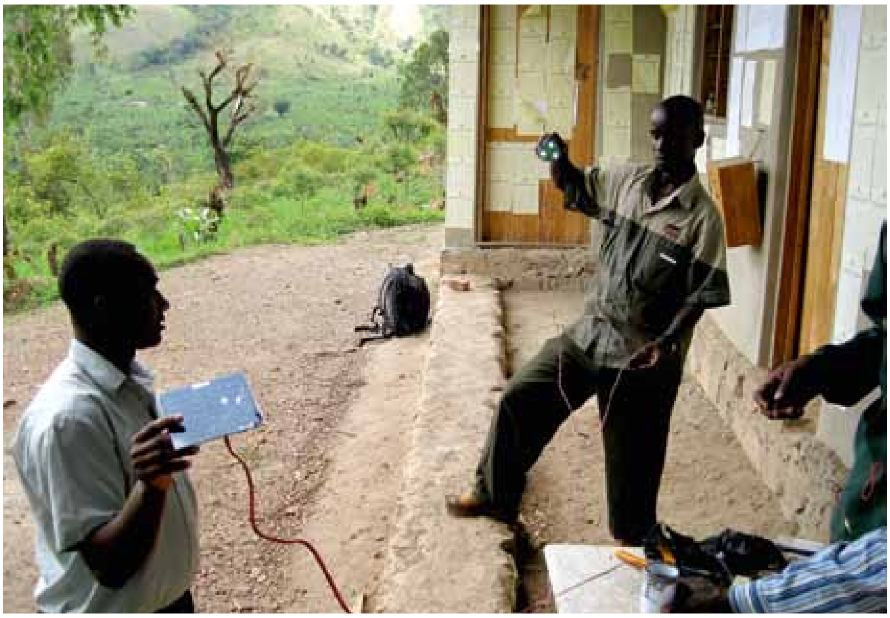
FINANCIAL ISSUES AND MANAGEMENT

In order to set up the micro-factories 7 manufacturing toolkits were purchased. In total, 17 kit system packages were bought from Green Energies LLC, each package comprising 25 kit systems (totalling 425 systems). The packages were loaned to the micro-factories with payment only being made once all 25 systems had been assembled, installed and sold. The repayments were collected by local project staff and transferred to Green Energies who then supplied the next packages.

The purchase price for one lighting kit is about 25-30 US$, while the retail price is as high as 40-65 US$. The prices are kept low by the regional distribution centre, which works on a non-profit basis. As the annual expenditure on kerosene for lighting by the average household in the project area is about 50-90 US$/year the installed LED lighting systems represented significant cost savings for the local population.

ENVIRONMENTAL ISSUES

During the project phase 270 lighting systems were installed (as of July 2010).



Estimating that each of these systems replaces 5 litres of kerosene per month for lighting, 16,200 litres/year of kerosene have been replaced. This equates to emission savings of 36,300kg CO_2/year. Expected sales of 500 lighting systems per month would result in even higher emission savings in the future.

Furthermore, the use of empty water bottles as a component of the LED lighting systems encourages conservation, whilst also saving money and adding value to the manufactured products.

The lifetime of the battery pack is about 2-3 years. Battery disposal needs to be organised by the micro-factories, which is assured if the users buy their new package at the micro-factory.

SOCIAL ISSUES

The project has a capacity-building element as local entrepreneurs were trained and employment opportunities were created within the local communities. Moreover, the lighting systems are designed to be affordable in order to meet the needs of the project's target group - low-income households. Due to the fact that "neighbours" (i.e. local entrepreneurs) install the lights, there is no difficulty in terms of contacting the installer should any problems arise.

The introduction of the LED lighting systems also helped to reduce indoor air pollution caused by the use of kerosene.

RESULTS & IMPACT

During the project 7 micro-factories were established, which have sold 270 LED lighting systems to rural farmers to date. The micro-factories have already taken action on their own initiative to respond to their customers' needs. The families who purchased the LED systems benefit from access to clean lighting and lower costs.

REPLICABILITY

Within the region the project could undoubtedly be replicated. The established regional centre has the capacity to work with more local entrepreneurs outside the initial target area to set up new micro-factories in other communities. In principle, the project structure could also be replicated in other regions. The micro-factories are easy and inexpensive to set up and the products sold are simple and light, which significantly minimises transportation logistics compared to larger solar PV systems. However, the project has benefited greatly from an ongoing project carried out by SCC-Vi Agro-forestry. Therefore, in order to replicate this project in other regions, more preparatory work would have to be done to engage with the local communities and to establish an appropriate financing mechanism.

LESSONS LEARNED

The implementation of the project revealed several factors that had not been considered during the planning phase. First of all, many potential customers demanded a mobile phone charging option. In response to this request, Green Energies LLC developed a new prototype. Additionally, some customers also requested a more aesthetically appealing design than the water bottles, even if this would mean additional cost. Some customers with larger homes also felt that the A3 lighting system was not sufficient, as it was designed for homes with small rooms. This resulted in discouraging some customers as they thought that they would have to purchase 2 systems to ensure sufficient lighting.

Another problem that occurred was the poor quality of locally available switches. After only a few weeks of installation the switching mechanism became loose and caused the lights to flicker and dim. To combat this, one micro-factory identified an alternative; they started using standard AC switches which are locally available, inexpensive and of better quality.

During the implementation stage of the project it was also discovered that business for the micro-factories peaked during the two harvest seasons and slowed down for the rest of the year. This was due to the additional available income during harvest season, meaning that farmers were more likely to buy a lighting system at that time. One micro-factory successfully targeted this fluctuation in sales by offering purchases on short-term credit.

Source: Final Report submitted to WISIONS by CAMCO

CASE STUDY 2

EFFICIENT LAMPS FOR NIGHT FISHING AT LAKE VICTORIA

PROJECT'S AIM

To replace kerosene lights for night fishing by introducing energy hubs to power sustainable lighting systems.

PROJECT DESCRIPTION

For generations, people on the shores of Lake Victoria in East Africa have been using kerosene lamps for night fishing. However, kerosene contributes to the degradation of the lake's ecosystem due to spillages, negatively affects health and is increasingly expensive as the international price of oil rises. As well as being polluted with kerosene, the ecosystem of Africa's largest lake is in an imbalance due to several factors: the introduction of the Nile Perch and its massive population growth, the introduction of foreign plants, deforestation of the surroundings and human population growth. Despite the negative effect that fishing has on the lake's ecosystem, the majority of the local people rely on this industry. One of the few species that has withstood the spread of the imported Nile Perch is the native Silver Cyprinid, locally known as Omena or Daaga. The sardine-like Omena is the region's major source of protein, especially for the poor. Every night, thousands of fishermen leave the shores in small boats and use kerosene lanterns to attract the fish to their nets.

This project aimed to introduce efficient, reliable and affordable replacements for kerosene lanterns. A new solar-based lighting technology was intended to improve food security, sustain the fishermen's livelihoods and safeguard the environment. This holistic approach simultaneously addresses the fishermen's social, economic and environmental needs . WISIONS supported the aspect of the project that addressed capacity-building, both of the fishermen and those people responsible for running the energy stations.

Location:
Lake Victoria, Kenya

Costs:
Total*: € 78,190
WISIONS financial support: € 51,000
*Cost of training/capacity building, not of technical equipment)

Partners Involved:
Global Nature Fund (www.globalnature.org)
Osram (www.osram.de/offgrid)
OSIENALA (Friends of Lake Victoria) (www.osienala.org)

Implementation Phase:
04/2008 – 06/2009

TECHNOLOGY, OPERATIONS AND MAINTENANCE

Kerosene lamps are commonly used in night fishing and for domestic lighting around Lake Victoria as 70% of the population lack access to electricity. Each fishing boat uses 5 lanterns and, because of their very low efficiency, every lamp consumes approximately 1.5 litres of kerosene per night. In a pilot project implemented by Global Nature Fund and OSIENALA it was proved that an 11W CFL (compact fluorescent lamp) gives comparable results to a kerosene lamp in terms of light intensity and colour. To introduce this technology it was necessary to construct a whole new energy system. The main elements of the new system, which was developed in collaboration with OSRAM, are solar energy stations, batteries and CFLs. Photovoltaic panels with a peak capacity of 9.3 kW are installed on the roof of each energy station and the electricity generated is used to charge the 12A/12V lead gel batteries. To maximise the batteries' life expectancy, they can only be recharged at the energy stations, which can charge 250 batteries per day. The batteries are equipped with two sockets for CFLs or other devices, such as mobile phones or radios. The lamps comprise 11W CFLs, white lampshades and waterproof cases.

The energy stations are managed professionally, thereby establishing livelihoods and fostering entrepreneurship. As well as the need for lighting, the energy stations address other fundamental needs in this off-grid region. As mobile phones become increasingly important in regions with poor infrastructure the need for charging stations grows rapidly. Therefore, the energy stations are equipped with a charging rack that can charge 48 mobile phones simultaneously. The purification of drinking water is another crucial function carried out at the energy stations.

FINANCIAL ISSUES AND MANAGEMENT

On average, a fisherman burns about 1.5 litres of kerosene every night - costing about € 1.50 (150 Kenyan Shillings, KES). The amount spent on kerosene accounts for approximately 30-50% of the fishermen's income. Solar powered lamps are not only cleaner and safer, but also cheaper. When completely charged, the batteries can power the 11 W energy-efficient lamps for one night. The charging fee for the battery is € 1 (100 KSE). To rent a battery lamp system the fishermen must leave a deposit of around € 20 (2000 KES). In the given context this is a lot of money but, as the running costs are about 30% lower than for kerosene lamps and the batteries can be used to power other devices such as mobile phones and radios, the deposit is a worthwhile 'investment'. When the fishermen return the lamps, their deposits are refunded.

ENVIRONMENTAL ISSUES

Around Lake Victoria kerosene is the main energy source for lighting, but burning kerosene for lighting purposes is highly inefficient as only 0.1% of the energy is converted into light (99.9% is converted into heat). The resulting CO_2 emissions are correspondingly high. As credible socio-economic data about the number of fishermen in the region and their fishing habits is unavailable, it is not possible to quantify the levels of CO_2 emissions. However, the following illustration gives an indication: the three energy stations in this project have 600 customers. Assuming that they previously consumed 120,000 litres of kerosene per year the resulting annual reduction in CO_2 emissions would be about 300 tonnes. Another positive environmental impact is the reduction in kerosene spillages, which pollute the ecosystem of the lake and reduce fish breeding.

Kerosene lamps are not only inefficient and pollutant, they are also unhealthy as they expose fishermen to toxic fumes. The new efficient lamps have no negative impact on the health of the users, although losing batteries in the lake by accident, as well as leakages from old batteries and lamps, can cause severe environmental damage. For this reason, the proper disposal of the batteries and lamps is crucial for ensuring the overall sustainability of the lighting system.

SOCIAL ISSUES

The proportion of family income spent on lighting decreased from 50% to 30% and the money saved has resulted in a higher standard of living. Additionally, the money now spent on lighting stays mostly in the country (as opposed to Petrodollars that leave the country and have a negative impact on the balance of trade). Furthermore, between 3 and 5 members of staff were employed at every energy station.

A key factor in the success of this project was the organisational structure around the lake. The fishermen are organised into groups of about 60 members in so-called 'Beach Management Units' (BMU). One key aspect of the project was the training courses given to the energy station staff, the representatives of BMUs, the fisheries officers and other stakeholders. Two workshops were organised in Kenya in order to provide the users with basic information on the technological, environmental and economic aspects of the energy saving lamps, on handling the batteries and lamps and about the services and prices of the energy stations.

RESULTS & IMPACT

The aim of the project was to serve around 1000 households by establishing 3 energy stations. The actual capacity is even higher: the 3 stations/hubs can serve around 3000 households. In total, the energy stations have about 600 customers who use the lamps, of which only 150 are fishermen. Although the clean, bright lamps were originally developed for use by fishermen, they are now increasingly used locally in households and small shops. Nevertheless, the project is sustainable and the number of customers is constantly growing . The general public was informed about the project via "Radio Lake Victoria", which reaches almost 10 million people around the lake and broadcasts in four languages.

The project partners had intended to introduce energy stations/hubs in Uganda, where training also took place. However, despite the positive results in Kenya, the technology was not well accepted in Uganda and by the end of the project the hubs had not been established.

REPLICABILITY

The potential for replication is enormous. 30 million people live on the shores of the lake, of which more than three quarters lack access to electricity. Replication is not restricted to Lake Victoria: in rural areas in developing countries kerosene lamps are often the only means of generating light for domestic use and work. Worldwide, around 77 billion litres of kerosene are consumed annually to generate light. An important factor for successful replication is the existence of some kind of productive use for the light (i.e. work/industry), as the consumers have to pay for it.

After the successful implementation of the first three hubs in Kenya, more followed in the following years. In future years GNF is even planning to establish energy stations/solar hubs in big cities (such as Nairobi).

LESSONS LEARNED

Initially the technology had teething problems and both the lighting systems and the batteries had to be adapted to the local conditions. Once the improvements had been made, however, the concept was up and running.

The technology and the business model is one important part of the project, but the social acceptance and the change in traditional habits is an entirely different matter of at least equal importance. This was a key challenge in Uganda, where the solar hub concept did not work. Disseminating the technology more widely depends on a well thought-out campaign and on the education of potential users about the many economic, social and environmental advantages of efficient solar lamps. In addition, the safe disposal of the lighting systems must be considered and professionally managed at the capacity building stage of the project.

Source: Final Report submitted to WISIONS by GNF

LIGHTING OUR WORKPLACES (AND MORE)

The lighting options presented here consider a wide range of non-residential buildings. The lighting needs are diverse; some typical examples include:

- High lighting levels for schools, offices and hospitals.
- Spotlights and colour possibilities for shops and warehouses.
- Warm, ambient lighting in hotels and restaurants.

Four main technical options from those presented earlier can significantly contribute to achieving energy savings in commercial and institutional buildings:

1. Use of highly energy efficient linear fluorescent lamps (LFLs).
2. Selection of appropriate and efficient luminaries.
3. Use of electronic ballasts.
4. Configuring adequate control systems.

The actual energy savings made depends on the type of lighting service required and, in the case of refurbishment, on the performance of the existing systems. The following hypothetical example illustrates the wide range of options:

If the current system consists of the most conventional LFLs (commonly known as 'T12' lamps) and conventional (electromagnetic) ballasts, the energy consumption can be reduced by 15% to 20% by simply changing the lamps for more advanced models, such as 'T8' lamps.

By combining the use of advanced lamps with the installation of efficient luminaries and electronic ballasts the total energy savings may be as much as 40% to 70%. In some cases, the total energy savings can be increased to 90% by using appropriate controls, such as daylight or motion detectors (see figure 6).

This illustrates the importance of considering the entire lighting system in order to achieve significant improvements in lighting quality and energy efficiency. Failure to do this seems to be particularly instrumental in hindering the wider adoption of efficient lighting practices in non-residential sectors. Therefore, we will discuss the crucial social and economic issues that relate to the challenge of switching to a 'lighting system' perspective.

Social Issues

There are a number of challenges to the wider adoption of efficient lighting systems. Some notable examples are outlined below:

- Inconsistent motivation for investment

Building owners, developers and investors have the most influence in determining what type of lighting will be used in new buildings. However, regularly, these actors are not the ones who pay the electricity bill. So the high upfront costs for installing efficient lighting solutions do not result in a direct financial benefit for the investors.

The final users, such as tenants or future owners, would probably be interested in reduced energy costs and a lower electricity bill but, in the case of new buildings, users are generally not involved in such decisions. And in the case of retrofitting measures, tenants are not inclined to make significant investment as they do not own the property and a long payback period could lower their financial benefit.

- Lack of awareness

Lack of awareness about the energy and cost saving potentials of efficient lighting is widespread within the construction industry e.g. amongst investors, architects, designers, developers and construction firms. In construction projects lighting is often regarded as a relatively irrelevant issue in comparison with other considerations and, therefore, the choice of energy efficient lighting solutions that best respond to the needs of specific buildings/rooms is often not a priority.

- Lack of technical know-how

Designing energy efficient lighting systems involves two main tasks:

1. Careful assessment of the actual lighting needs, which depend on variables such as the purpose and the physical characteristics of the buildings or places.
2. The appropriate combination of technical components, e.g. lamps, ballasts, controls, luminaries, room characteristics, windows, reflectors, etc.

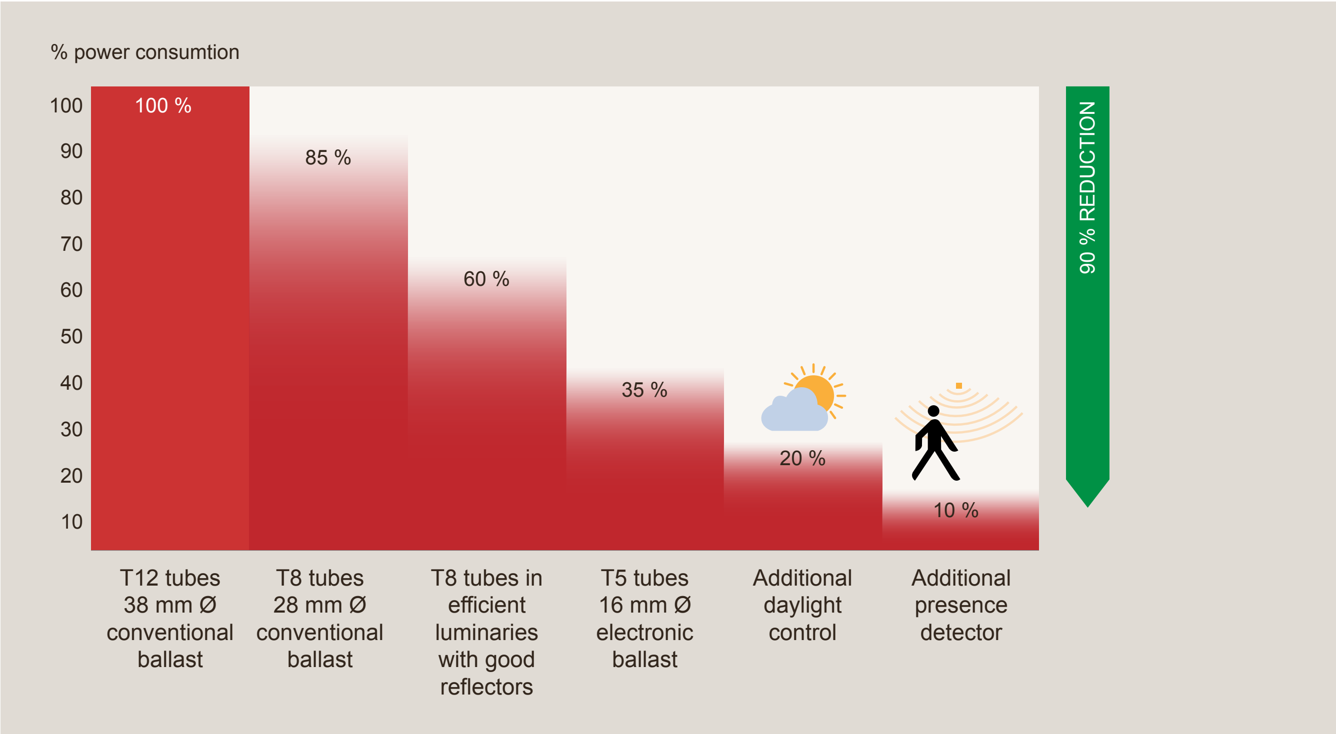


Figure 6. Potential energy savings from combining appropriate lighting technologies.
Adapted from: “Better Lighting Saves Money” (Seifried, 2009)

Many technicians, architects and other industry players lack the know-how to cope with these diverse challenges and this is still a major obstacle to accelerating the wide-ranging implementation of efficient lighting technologies.

Economic issues

Installation costs of energy efficient lighting systems are generally higher than for most conventional solutions. Not only is the price for advanced (energy efficient) components higher, but also better lighting solutions regularly require the application of less common lighting controls.

Evaluating the actual economic benefits that derive from the installation of energy efficient lighting systems requires an estimation of the cost of the life cycle of the system to be made, and for this to be compared to the cost of the existing system (in the case of a refurbishment) or to the cost of the most common alternatives (in the case of new projects).

Financial savings are anticipated from three main improvements:

- Lower electricity bills: because the more efficient lighting system consumes less power.
- Fewer maintenance requirements: a well-balanced selection of robust and compatible components is particularly important to benefit from this advantage.
- Less frequent replacement of lamps: the lifespan of lamps can be significantly improved by using appropriate ballasts and control strategies.

A common analytical approach is to calculate the payback period required i.e. how long it will take to pay back the initial investment by offsetting these initial costs against the expected cost savings.

The cost savings that can be achieved depend on several factors:

- The design of the building/room
- The purpose of the building/room
- The availability of natural daylight
- The performance of the current system (in the case of refurbishments)
- The electricity tariff

The case study from the national university in Mexico City (UNAM) (Case Study 3 of this publication) illustrates well how diverse the economic performance can be of efficient lighting measures. In this project, measures for improving lighting quality and energy efficiency were proposed for four different kinds of spaces. The payback period for each measure ranges from less than 2 years to over 10 years.

LINEAR FLUORESCENT LAMP

Linear fluorescent lamps (LFLs) are the most traditional option for lighting systems in working and learning environments and in commercial buildings. They became very popular in the first half of the 20th century. The first commercial and most widely distributed type of lamp, called T12, consists of a glass tube with a diameter of 38mm.

Today more advanced products are available – the T8 and T5 lamps – and these can reduce the total energy consumption by more than 50%. Even though these more efficient technologies have been available for several decades, around 40% of the lighting in the global commercial sector is still provided by the old T12 technology [2]. This means that significant energy saving potential is still to be exploited.

Environmental Issues

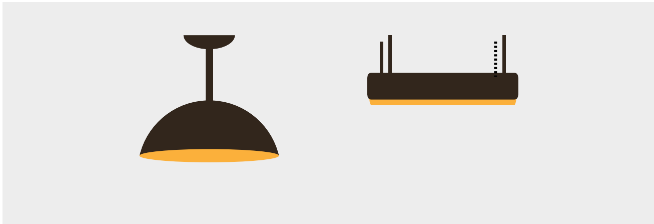
Improved LFLs can offer a significant contribution to efforts to reduce the levels of greenhouse gases (and other hazardous emissions) related to the provision of electric power.

The major concern relating to this technology is the emission of mercury during the disposal phase. Recycling technology that allows for the recovery of mercury and other valuable materials from spent lamps is already available. The development of appropriate schemes to ensure high recycling rates is needed in order to mitigate the potential environmental impacts from the disposal of LFLs. T5 lamps only contain very low levels of mercury compared to T12 lamps and are, therefore, also preferential for this reason.

Development status and prospects

The technology used in the highly efficient LFLs is mature. Even the most advanced technologies have been on the market for several decades – T5 since the early 1980s and T8 since 1951 – and a broad range of products are commercially available.

EFFICIENT LUMINARIES



The selection of the luminaire can significantly affect the overall energy efficiency of a lighting system. The efficiency of luminaries is commonly measured by the so-called light output ratio (LOR), which is the fraction of light output from the luminaire in relation to the light (originally) emitted by the lamp. The LOR can vary between 0 and 1 and ideally a luminaire should have a LOR higher than 0.8.

Although the LOR provides an indication of the efficiency of a luminaire, it does not take into account other relevant quality aspects of lighting systems [2]. The use of appropriate diffusers might reduce the LOR but improve the illumination of a room. Therefore, the careful selection of luminaries that are better adjusted to the lighting situation of a room may result in a reduction in the amount of light sources needed i.e. fewer lamps for the same level of light.

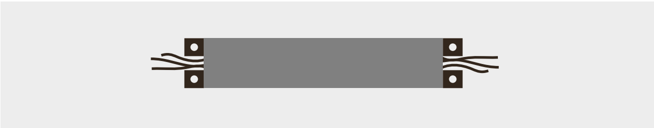
Environmental Issues

Whilst in operation, luminaries do not generate emissions or produce any other detrimental environmental effects. Environmental impacts are associated with the production phase and the lifecycle i.e. the use of resources, energy consumption and waste production. If good recycling facilities are available for luminaries, this significantly improves the overall environmental performance of the product as most of the conventional parts or materials can be reused or recovered.

Development status and prospects

A broad range of designs of luminaries are available, responding to very specific requirements for different kinds of lighting situations. However, the actual availability of luminaries varies between countries or regions.

ELECTRONIC BALLASTS



Ballasts are power regulation devices that are required by most electric lamps. Ballasts operate using electric power and their power consumption should be taken into account when assessing the energy losses of a lighting system. Ballasts are basically classified into two categories – electromagnetic and electronic. Electromagnetic ballasts are the cheaper and most common option, although they are less energy efficient than the electronic ballast.

Electronic ballasts work by using electronic circuits to provide the required ignition and operational power for one or more lamps. In addition to reducing loss of power, the use of electronic ballasts results in other improvements when compared to electromagnetic options. Some of the advantages are:

- Electronic ballasts can operate at high frequencies (above 10kHz), which improves the effectiveness and lifespan of the lamp and avoids the light flickering.
- Electronic ballasts are easier to integrate into lighting control strategies e.g. when building energy management systems or using daylight dimming sensors (see lighting controls).

Environmental Issues

By reducing energy losses and facilitating the optimisation of lighting services, the use of electronic ballasts can lead to a reduction in greenhouse gas emissions related to power generation.

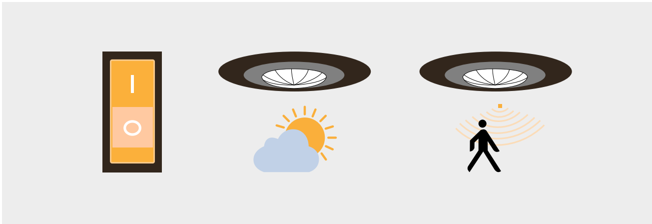
During operation, ballasts do not generate emissions (except for those related to their own power consumption) or produce any significant detrimental environmental effects. The main environmental impact relates to the production phase i.e. in terms of energy consumption, use of resources and waste production. The disposal of used ballasts is also relevant and, therefore, availability of well-functioning recycling systems is important, as most of the components and materials used in ballasts can be recycled.

Special care should be taken when replacing certain older electrical lighting components, as they may contain harmful substances. This is the case in some capacitors, which contain Polychlorinated Biphenyl (PCB) as dielectric fluid. Such capacitors are still found in old equipment and should be treated as hazardous waste.

Development status and prospects

Energy efficient ballasts are already commercially available. Products are suitable for a wide range of different functions e.g. 100% dimming, automatic recognition of the lamp type and automatic adaption of the power supply, special lamp starting controls to mitigate the adverse effects of frequent switching and the possibility of operating several lamps with different power requirements.

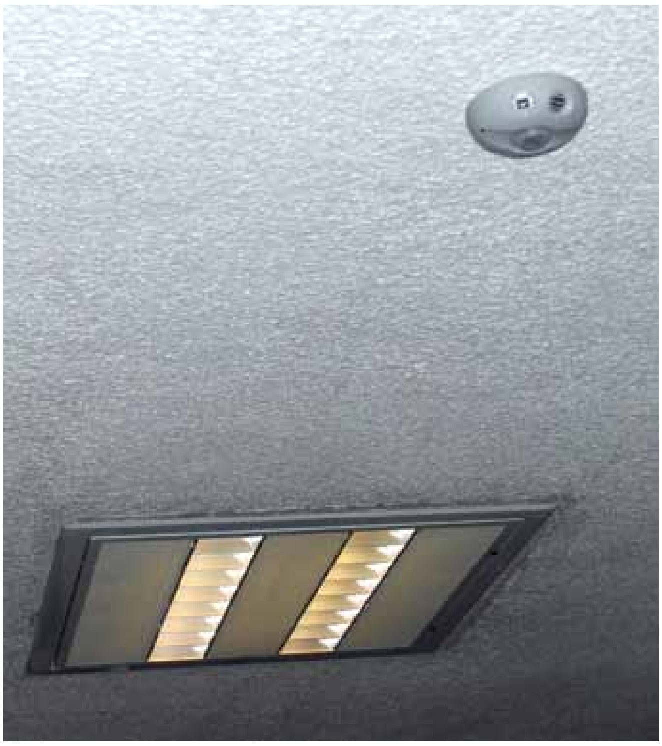
LIGHTING CONTROL



Controlling the supply of artificial light to meet specific lighting requirements can make significant energy and cost savings. This is true for all scenarios, from a single electric lamp to an entire lighting system in a building complex.

Examples of situations where energy savings can be made include:

- Rooms or corridors with large windows or transparent walls where electric lights are continually on regardless of the supply of natural daylight.
- Illuminated rooms (e.g. bathrooms), corridors or stairways that are empty during long periods.



These are only some examples of the types of buildings or locations that could benefit from significant energy savings by using appropriate lighting control systems. Lighting control technologies comprise a combination of devices and control strategies that allow for the provision of lighting services that can be varied in accordance with actual levels of natural daylight and the needs of the location. Some key elements of lighting control are described in the following sections:

- Lighting scenes

Different areas within a single room or space may require different levels of lighting. The differences in lighting requirements may result from situations such as:

- Different occupancy patterns: e.g. a large room with several working areas that are used at different times.
- Different tasks: e.g. a sports facility requiring different lighting levels for events compared to cleaning or maintenance.
- Different levels of daylight: e.g. in rooms with natural daylight the need for artificial light during the day depends on the distance of each working place to the windows and on how bright or dull the natural daylight is, which may change during the course of the day.

In these cases, if a single switch operates the entire lighting system the lights will always be fully on, even when only a small amount of artificial light would be needed to meet the actual demand. The simplest control strategy consists of defining "scenes" (i.e. individual areas with specific lighting needs), serviced by sets of lights that are controlled by separate switches. In this instance, the user manages the control strategy by manually switching one or several specific scenes on or off according to the light levels required.

The control strategies can also involve different levels of automation, such as programming the operation of the lighting system according to daily usage patterns, adjusting the light output of the lamps according to levels of natural daylight, automatically switching lamps off after a determined period of time (temporising) or according to occupancy etc. Occupancy sensors and photo sensors are components that, in part, make up these types of automatic controls.

- Occupancy sensors

These are devices that detect the presence of users within a defined area. They are used to avoid lighting unoccupied areas.

There are three types of occupancy sensors, which differ in the way in which they function:

1. Passive infrared: detects the presence of heat-emitting bodies.
2. Ultrasonic: emits inaudible sound signals and detects the movement of bodies based on the reflection of the sound signals.
3. Hybrid: combines both principles (infrared and ultrasonic) in order to reduce the probability of false detection.

- Photo sensors

Photo sensors are used to detect the level of lighting at a specific point. Different control strategies can be used to vary the lighting levels based on parameters detected by the photo sensor. The most basic control is to turn the lamps on or off. Another option is to vary the light output of the lamps (dimming) according to the information provided by the photo sensor. More complex strategies can involve other factors, such as occupancy patterns, in order to control the operation of the lamps.

Environmental Issues

By optimising lighting services the installation of lighting controls can decrease the demand for electric power and, therefore, help to reduce the levels of greenhouse gas emissions related to electric power generation.

During operation, lighting controls do not generate emissions or cause any significant detrimental environmental effects. From a lifecycle perspective, negative environmental impacts relate to the production phase i.e. in terms of energy consumption, use of resources and waste production [8]. However, these effects are generally accepted as being rather marginal.

Development status and prospects

A wide range of lighting controls is commercially available. As well as single components (such as sensors and switches), some manufacturers already offer luminaries with integrated elements for lighting control (e.g. different kinds of sensors and appropriate ballasts).

CASE STUDY 3

EFFICIENT LIGHTING FOR THE UNIVERSITY OF MEXICO CITY (UNAM)

PROJECT'S AIM

To demonstrate that the improvement of lighting efficiency in universities/public buildings can lead to major electricity and cost savings.

PROJECT DESCRIPTION

Lighting accounts for 20% of the global demand for electricity and, especially in schools, universities and other public buildings, lighting costs constitute the major share of the electricity bills. The development of a more efficient lighting system in educational institutions can therefore result in major electricity and cost savings.

To highlight the potential benefits of efficient lighting, the Büro Ö-quadrat and the UNEP/ Wuppertal Institute Collaborating Centre on Sustainable Consumption and Production (CSCP), accompanied by their Mexican counterpart the Genertek S.A., conducted a pilot project. The project was carried out at the oldest University in the Americas, the National Autonomous University of Mexico (UNAM). It consisted of four model lighting modernisation projects in four typical areas of a university: classroom, library, foyer and workshop/ laboratory of the Institute of Engineering. Based on the experience gained from these model areas a master plan for the entire campus of UNAM was developed, including possible financing options. The results and possibilities for future development were then presented to the university administration, to local politicians and to interested faculty staff and students in September 2009.

TECHNOLOGY, OPERATIONS AND MAINTENANCE

The upgrade of a lighting system is a complex process. Commonly available technologies were used for the model modernisation projects at UNAM. The systematic approach that was chosen consisted of several steps. First the required degree of lighting was determined. Following that, the room interior was redesigned to create the best possible conditions for light reflection. This was accomplished, for example, through brighter walls, ceilings and floors. The reflection of the incident daylight reduced the need for additional lighting. The next step was to choose the most suitable efficient technology.

At UNAM, electronic ballasts that can be dimmed were used and more efficient T5 tubes replaced the old T12 tubes. Next, daylight sensors were installed to minimise the need for artificial lighting. Finally, presence detectors were installed to ensure that lighting is only active when the room is in use.

FINANCIAL ISSUES AND MANAGEMENT

The initial investment for modernising the lighting in the four model areas was € 10,900. As a result of the modernisation, 84% less electricity was used than previously, which represents cost

Location:
Mexico City, Mexico

Costs:
WISIONS financial support: € 50,700

CO_2 Reduction:
20,000kg CO_2/year

Partners Involved:
Büro Ö-quadrat
(www.oe2.de)
UNEP/ Wuppertal Institute Collaborating Centre on Sustainable Consumption and Production (CSCP)
(www.scp-centre.org)

Implementation Phase:
12/2006 – 09/2009
(with interruptions)

Table 2. Summary of measures carried out to upgrade the lighting system in two different types of rooms and the resulting energy savings

Adapted from "Better lighting saves money" [10]

Class room / Laboratory

Former System

Upgraded System

	Former System	Upgraded System
Lamps per fixture	2 x 32 W (T8)	1 x 28 (T5)
Ballast	Conventional	Dimmable, electronic
System power	60 W	33 W (max)
Luminaire efficiency	40%	75%
Daylight control	no	yes
Presence control	no	yes
Illuminance level	374 Lux	438 Lux
Electricity saved	-	**72%**
Payback period	-	**5.4 years**

Foyer

Former System

Upgraded System

	Former System	Upgraded System
Lamps per fixture	2 x 20 W (T8)	2 x 14 (T5)
Ballast	Conventional	Dimmable, electronic
System power	96 W	33 W (max)
Luminaire efficiency	35%	84%
Daylight control	no	yes
Illuminance level	123 Lux	180 Lux
Electricity saved	-	**90%**
Payback period	-	**1.3 years**


Example of improvement of lighting system in the Rivero Borrel library. Left: former system (without daylight control). Right: upgraded system (including daylight control).

savings of € 3,540 per year. The average payback period for all four rooms was, therefore, just short of three years. And the longer the existing lighting has been in use, the shorter the payback time on the investment.

With regards to the modernisation of the entire university, the master plan that was developed suggested initial investment of € 2.4 million and total investment of € 10.9 million. The savings in energy costs over the lifecycle could amount to as much as € 53.4 million, which would result in a net return of € 42.5 million. It is now up to the faculties and the university management to take further action to improve the lighting efficiency across the whole of UNAM; the pilot project has demonstrated that this is possible and feasible.

ENVIRONMENTAL ISSUES

If the master plan were to be implemented, the estimated electricity savings would be 19 million kWh. This would result in a reduction in carbon emissions of 266,000 t over a lifecycle of 20 years. The existing model lighting project saves 28,231 kWh per year, which equates to a reduction in carbon emissions of as much as 20 t/year.

SOCIAL ISSUES

The improvement of the lighting situation at UNAM created a better learning and working environment for the students and staff. The newly designed areas offer not only more light but also a better atmosphere. In addition, awareness of lighting efficiency issues has been raised amongst the students and interested engineers, as they now have had the chance to learn from direct experiences in their environment.

RESULTS & IMPACT

The pilot project at UNAM has shown that significant energy and cost savings in public buildings are possible through the implementation of efficient lighting technologies. In addition, the project has made clear that the payback period depends on the age and quality of the existing lighting.

So far the project has had no further concrete impact, as the university administration has not yet taken steps to implement the master plan. However, various faculty members, as well as the Mexican consulting firm who contributed to the project, showed a significant interest in supporting and implementing further lighting efficiency improvements at UNAM. Table 2 summarises the main measures carried out and their effects.

REPLICABILITY

The lighting situation at UNAM is not unusual in universities, schools, offices, banks etc. in Mexico; the same applies to many public buildings around the world. In fact inefficient lighting is widespread and there are many opportunities for cost-effective energy savings. For example, some of the university buildings in Freiburg, Germany also have inefficient lighting. Furthermore, the technology deployed at UNAM is commonly used and can, therefore, be utilised on a large scale. As with most projects, the critical factor is the initial financing.

LESSONS LEARNED

Several delays occurred during the project, due mainly to administrative factors that included some communication issues between the project team and the university administration. Future projects should, therefore, try to involve the institution's management team at the outset of the project to ensure productive and regular communication between the project team and the management.

Source: Final Report submitted to WISIONS by Ö-quadrat

CASE STUDY 4

RENEWABLE ENERGY AND ENERGY EFFICIENCY IN THE INDIAN URBAN HEALTH SECTOR

PROJECT'S AIM

To improve health services for the poor in the city of Bhubaneswar, resulting in greater local socio-economic development and reduction in fuel poverty.

PROJECT DESCRIPTION

Over the past 50 years India's urban population has been dramatically increasing, with most people living in slums or other substandard dwellings. People in these low-income communities face major health hazards due to poor living conditions, lack of hygiene and sanitation, dependency on untreated water supplies and significant exposure to indoor air pollution. Most of the inhabitants depend on health care services provided by local government. The level of health service provided varies from city to city and local governments are becoming increasingly concerned about their ability to meet their social obligations in the health sector. At the same time, most Indian cities are facing a severe energy crisis, which also has a negative affect on health care services.

Recognising the serious nature of these problems, the issue of energy in the urban health sector in India was addressed by a project carried out by the South Asian group of ICLEI - Local Governments for Sustainability. The project team focused on identifying and implementing renewable energy technologies and efficiency measures within hospitals. Hospitals are large consumers of energy; they need power supply for lighting common areas and operating theatres, providing hot water, refrigerating vaccines and medicines etc. Additionally, alternative sources of energy are needed for emergency services during power shortages.

Initially, ICLEI carried out a detailed assessment of the energy consumption in local authority health care facilities in the city of Bhubaneswar, India. One hospital was then chosen as a pilot project to demonstrate that renewable energy technologies and energy efficiency strategies could be a way of tackling the hospital's energy issues. An expert conducted an energy audit at the hospital in order to identify possible areas of intervention. Based on the results of this audit, recommendations for action were formulated. The proposed technologies were: a solar photovoltaic power plant, solar water heating installations, a solar-powered vaccine refrigerator, solar lighting systems with energy efficient light fixtures and efficient ceiling fans. The necessary equipment was procured and installed and then the hospital staff was trained in the operation and maintenance of the equipment so that they would be able to use it on a daily basis.

Location:
Bhubaneswar in the state of Orissa, India

Costs:
Total: € 57,200
WISIONS financial support: € 47,800

Partners Involved:
ICLEI, Local Governments for Sustainability, South Asia
(www.iclei.org/sa)

Implementation Phase:
04/2008 – 11/2009

TECHNOLOGY, OPERATIONS AND MAINTENANCE

The site chosen for the pilot project is a two-storey hospital facility spread across two buildings covering a total area of 14,000 m^2. It is the second largest hospital in the city of Bhubaneswar with approximately 300,000 - 400,000 people living in its catchment area.

The technologies installed encompass a 1.28 kW photovoltaic power plant that is designed to provide backup power for 4 hours per day. With full radiation it can convert up to 5 kWh of electricity. In addition, a solar water heating system with a flat plate collector was installed. This system can provide 200 litres of hot water per day to cater for the needs of the gynaecological department and the operating theatres. A solar-powered refrigerator was also installed, which helps to ensure the safe and efficient preservation of temperature sensitive vaccines e.g. live polio vaccines and other biological materials. In addition, internal and external solar lighting systems were installed – a total of 8 sets indoors each with 9W capacity and one 11W weatherproof external light set. The efficiency measures included the replacement of regular light bulbs with CFLs (T5 28 W LFLs and 25 W CFLs), which are four times more efficient. Finally, regular heavy weight ceiling fans were exchanged for energy efficient fans that consume far less electricity for the same level of performance.

Trained hospital staff will carry out the daily operation and maintenance of the systems, but the suppliers are responsible for the annual maintenance of the equipment for the first 3-5 years.

FINANCIAL ISSUES AND MANAGEMENT

The cost of installing the renewable energy technology was € 14,000, while the energy efficiency fittings amounted to € 3,850.

In the first few months after installation the hospital achieved overall energy savings of 15% compared to previous levels. This could potentially translate into savings of € 800 per year (around 14300 kWh).

The local government did not contribute financially to the project, as confidence in successfully integrating renewable energy technologies and energy efficiency measures into the urban health care sector was very low at the outset. The success of the project may have helped to change these attitudes.

ENVIRONMENTAL ISSUES

There were a number of beneficial environmental outcomes of the project. Solar power replaced the fossil fuel-based energy that was previously used to provide backup energy during a power shortage. Also, by changing to energy efficient technology within the hospital buildings, less grid electricity is now required. This has resulted in estimated emissions savings of 200,000 kg CO_2/year.

SOCIAL ISSUES

Improving the reliability of the hospital's energy supply and providing the equipment to refrigerate vaccines and medicine has helped to provide a satisfactory quality of health service for the urban poor who mainly frequent the hospital.

RESULTS & IMPACT

One hospital in the city of Bhubaneswar was equipped with a variety of solar energy technologies and efficient light bulbs and fans. The project demonstrated that renewable energy and energy efficiency applications could be technologically, financially and environmentally feasible in the urban health sector in India. The new energy efficient approach at the hospital became a showcase for the participants of the Climate Roadmap Subnational Workshop in 2009. Furthermore, the mayor of Bhubaneswar has promised to take steps to include renewable and efficiency strategies in the future development of the city.

REPLICABILITY

Within the Bhubaneswar Municipal Corporation area there are 6 public hospitals, 2 private hospitals, 17 government dispensaries and about 20 nursing homes, as well as many private clinics. All these sites could potentially benefit from renewable energy technologies and efficiency measures. However, there is no commitment at present from local government to make further investment in this area. Additionally, each health centre has different conditions (i.e. building construction, energy demand etc.), which means that a bespoke plan would be required for every single health centre. On the other hand, India's local governments have begun to appreciate the importance of renewable energy sources and energy efficient technologies. The successful implementation and the economic and environmental benefits of the project might increase the confidence of local governments and lead to further replication in India or globally.

LESSONS LEARNED

Overall the project has proven that renewable energy sources and efficiency installations can reduce energy use in a hospital, while also providing energy security. Despite this, funding will be difficult to secure as local governments already struggle to fulfil their obligations in the health care sector. Additionally, the maintenance of the installations is not assured after the initial 3-5 years, which could become a problem if funding for repairs cannot be found.

Source: Final Report submitted to WISIONS by ICLEI South Asia

CASE STUDY 5

IMPROVING ENERGY EFFICIENCY ON THE UNIVERSITY OF MAURITIUS CAMPUS

PROJECT'S AIM

To improve the energy performance on campus through efficient appliances, PV system and awareness-raising campaigns.

PROJECT DESCRIPTION

This project was part of an "Eco-Campus Initiative" that was implemented by the University of Mauritius (UoM). The objectives were to improve the environmental performance of the university campus and to increase environmental awareness among staff and students. By doing this, UoM aimed to contribute towards sustainable development through education, research and interaction with the wider community. The efficiency improvements made in the lighting on campus should, also, serve as an example for other institutions in Mauritius.

The holistic project approach addressed both the technical and the social/human components. The technologies that were chosen to achieve the objectives included compact fluorescent lamps (CFLs), power factor correctors and photo sensors, as well as a photovoltaic system for the street lighting on campus. The second target, to raise awareness both within the university and the wider community, was achieved through a public information campaign about energy efficiency and the possibilities for changing personal behaviour. The information campaign made use of different means of communication such as brochures, posters, websites and workshops.

Location:
University of Mauritius, Mauritius

Costs:
Total: € 36,500
WISIONS financial support: € 33,000

CO_2 Reduction:
Ca. 45,000 kg CO_2/year
(new installed hardware only)

Partners Involved:
University of Mauritius (UoM)

Implementation Phase:
08/2008 – 02/2011

Webpages:
http://sites.uom.ac.mu/eco_campus/

TECHNOLOGY, OPERATIONS AND MAINTENANCE

In order to improve the efficiency of the indoor and outdoor lighting, all the existing incandescent bulbs (around 500) were replaced by 14 W CFLs. These new and more efficient lamps use better electrodes and coatings and produce about the same lumen output with substantially lower wattage. By substituting the old bulbs for the new CFLs, energy savings of as much as 60% – 75% are expected. A survey was also carried out to measure the illumination levels of all the rooms on campus and to identify all the light fixtures that would need to be changed in the future.

Two power factor correctors were also installed. This technology is a way of reducing electrical load and minimising wasted energy, resulting in improved efficiency and lower electricity bills. The installation of additional power factor correctors, particularly in cases where a number of electricity meters are in operation, would help to achieve electricity and cost savings. Combining metering systems, and using photo sensors, would also provide savings in terms of maximum demand and meter rental fees.

In addition, for external night lighting a 2.5 kW solar-powered PV system was installed in February 2011 on the roof of the engineering tower. It consists of fourteen 175W solar modules. An inverter converts DC input voltage into AC voltage to fulfil the requirements of the grid to which the

PV system is connected. UoM expects to receive feed-in tariffs for Small Independent Power Producers (SIPP), an initiative that was recently launched by the government. The operation and maintenance of the equipment purchased through this project is the responsibility of UoM technicians in collaboration with the suppliers.

FINANCIAL ISSUES AND MANAGEMENT

The project is expected to be economically feasible due to the predicted reduction in energy consumption and associated energy costs. The use of CFLs should result in an annual saving of 250,000 Rs (around € 5,000). These savings will be invested in long-term information campaigns at UoM, such as annual energy-efficiency campaigns to promote energy saving among new students.

An internal team from different departments, led by Toolseeram Ramjeawon, Professor in Environmental Engineering, managed the project.

At the beginning of the project there was no commitment from UoM's top management team, but now that the Eco-Campus Initiative has proved to be a success the university management is keen to introduce further energy efficiency measures on campus. For that purpose an Energy Audit Team has been formed under the authority of the vice-chancellor.

ENVIRONMENTAL ISSUES

The primary source for generating electrical energy on the island of Mauritius is fossil fuel (about 80%). Therefore, reducing the energy consumption at UoM results in the parallel reduction of primary fossil energy use. With expected annual electricity savings of about 45,000 kWh, CO_2 emissions would be reduced by around 45,000 kg/year (by the new installed hardware). In addition, it is expected that the increased awareness among staff and students will lead to a decrease of electrical energy consumption at household level.

There are some environmental risks arising from the disposal of CFLs due to the mercury they contain and this problem has not yet been solved. It will be necessary to establish a programme that manages the disposal of used CFLs.

SOCIAL ISSUES

The improved lighting situation at UoM has created a better learning and working environment for students and staff. The newly designed areas do not only offer more light but also a better atmosphere, because insufficient light or darkness gave rise to a sense of insecurity. Improving the artificial outdoor lighting on the campus has also improved the safety of students and staff.

Added to this, the awareness-raising element of the project offered the possibility for behavioural changes amongst students and staff. This has the potential to lead to even bigger energy savings because behaviour is considered to be the key component in reducing energy consumption.

In terms of academic education, a module on "Sustainable Energy Consumption" has been developed and this will become part of an Education Module on Sustainable Development from the 2011/12 academic year.

RESULTS & IMPACT

All incandescent lamps on campus were changed, efficient devices and the PV system were installed and a survey of light fixtures and illumination levels was carried out to identify further efficiency improvement opportunities. In addition, different communication tools such as posters, mouse mats, stickers etc. were created to raise awareness amongst staff and students about energy saving and two websites were launched http://www.uom.ac.mu/SaveEnergy/ and http://sites.uom.ac.mu/eco_campus/. In addition, UoM and the Central Electricity Board (CEB) organised a joint workshop.

REPLICABILITY

Theoretically, the improvements made in the efficiency of the lighting on campus could be replicated in all educational institutions in Mauritius, as well as in government institutions. The University is the first educational institution in Mauritius to have a PV system and this type of grid-connected system could also be replicated. Positive factors for replication are the relatively low investment costs and the potential economic savings - especially as energy prices continue to rise. However, even though the initial investment costs are low, securing sufficient funding will not be easy.

LESSONS LEARNED

The project provides evidence that a successful demonstration of the benefits of increased lighting efficiency can positively change the opinions of the stakeholders involved. This has paved the way for implementing further lighting efficiency measures at UoM, and other institutions, in the future. In terms of lessons learned, it should be noted that the project was delayed due to problems with the procurement of the PV system.

Source: Final Report submitted
to WISIONS by Professor T. Ramjeawon, UoM

Picture: UoM

CASE STUDY 6

INTRODUCTION OF EFFICIENT LAMPS FOR NIGHT FISHING IN SRI LANKA

PROJECT'S AIM

To improve the livelihoods of fishermen at lakes in south-west Sri Lanka by replacing kerosene lamps with LED and CF lamps for night fishing.

PROJECT DESCRIPTION

This project was implemented at the lakes and wetlands of Bolgoda, Madampe, Maduganga, Maella, Malal and Lungamwehera in Sri Lanka. Bolgoda is the largest natural lake in Sri Lanka with a rich biodiversity. Over 40 fish species live in this stretch of water and the local communities rely heavily on the fish and prawns as a main source of food and income. At the lakes fishermen traditionally use kerosene lamps for night fishing with canoes and for catching prawns in traditional Ja-Kotu systems. The introduction of efficient lamps, specifically LEDs and CFLs, for night fishing was intended to reduce the use of fossil fuels and its associated negative effects on health and the environment. From an income perspective it is also important to reduce dependence on fossil fuels as their price on the world energy markets is rising and becoming increasingly volatile.

The project was coordinated by Global Nature Fund and was implemented by the local partner organisations EMACE Foundation and Nagenahiru Foundation. The project started with a detailed socio-economic survey to obtain clear data about the lighting systems already in use and the number of fishermen in the region who carry out night fishing. As well as introducing sustainable lighting systems, training the users and technicians was another important element for the success of the project.

TECHNOLOGY, OPERATIONS AND MAINTENANCE

The first part of the project relates to the prawn catching. The traditional prawn catching systems called Ja-Kotu are made of interwoven bamboo panels which consist of two units of three interconnected catching chambers fitted with non-return devices. Fishermen light seven kerosene lamps in each Ja-Kotu, six in each catching chamber and one lamp at the outer stand. The seven kerosene lamps consume between 3.0 and 3.5 litres/kerosene per night.

In the context of this project 50 prawn traps were equipped with LED systems. Special attention was paid to the colour and light intensity of the different LED lamps as these factors were important for ensuring the acceptance of the new lighting systems by the fishermen. Each Ja-Kotu is fitted with 6 LEDs and a 12V (20 Amp) sealed lead battery to power the LEDs.

The second part of the project relates to the fishing with canoes. Traditionally, during the night, fishermen light kerosene lamps to illuminate and attract fish in rivers, tanks and lagoons. In the context of the project 500 kerosene lamps were replaced by CFLs. The design is powered by a rechargeable 12V 4-6 Amp sealed lead acid battery.

Six service centres were set up in the project area to manage the maintenance of the new lighting systems and the capacity-building of the fishermen. The centres provide technical support, educate the fishermen to handle the new systems, hand out spare parts, carry out minor repairs, replace batteries and bulbs and give information on the recycling system

Location:
South-west wetlands of Sri Lanka

Costs:
Total: € 88,770
WISIONS financial support: € 56,500

CO_2 Reduction:
400 to 600 t/year

Partners Involved:
Global Nature Fund
(www.globalnature.org/livinglakes)

EMACE Foundation, Sri Lanka
(www.emacesrilanka.com)

Nagenahiru Foundation, Sri Lanka
(www.nagenahiru.org

Implementation Phase:
01/2009 – 12/2010

for batteries and bulbs. Moreover, the centres maintain quick-charger systems to recharge batteries quickly. As the national electricity grid in Sri Lanka covers the project area and electricity is subsidised, in general the batteries are charged by conventional electricity from the grid. But for demonstration and testing purposes sixteen 30W photovoltaic units are used by Ja-Kotus to charge the batteries in an environmentally sustainable way.

FINANCIAL ISSUES AND MANAGEMENT

The monthly payments for the kerosene lighting systems were about € 15 (SLR 2500) for each canoe fisherman and € 50 (SLR 8200) for a Ja-Kotu team of 7 to 8 fishermen. This is up to 30% of the monthly income. The steep price increase of kerosene on the world market since 2004 and the reduction of Sri Lankan subsidies for fuel created an environment where fishermen were willing to test the new efficient lighting systems in order to gain economic advantage. The running costs of the new systems, mainly the charging of the batteries, are negligible, because electricity is still (due to subsidies) relatively cheap. But most fishermen face difficulties in paying the initial cost of € 36 to € 45 (SLR 6000 to 7500) upfront, although this amount is already subsidised by 50%. To alleviate this obstacle the fishermen can make the payment in 5 monthly installments of about SLR 600 (€ 3.60). This payment is low in relation to the running costs of kerosene lamps. Due to this economic advantage, many fishermen in the region have become interested in using efficient lighting systems.

ENVIRONMENTAL ISSUES

Burning kerosene for night fishing has several environmental disadvantages: from a global perspective the CO_2 emissions are the central factor. In this project, CO_2 emissions were reduced by roughly 400 to 600 tonnes per year (the variance depends on the estimates about the average number of nights in a year that are used for fishing; estimates ranging from 180 to 300 nights). This high reduction results from the very inefficient conversion of kerosene to light. In the process of burning kerosene, most of the energy is converted to heat and not light. Local disadvantages of using kerosene for night fishing are the accidental kerosene spillages that cause pollution of the ecosystem and contaminate the water and the catch.

SOCIAL ISSUES

The financial burden for the fishermen of using kerosene for night fishing is significant. Fuel costs alone consume between 20% and 30% of the household income. The efficient lamps, therefore, enable the fishermen to have more disposable household income. In addition, the better performance of the new lighting systems (in comparison to the traditional kerosene lamps) benefits the fishermen and prawn catchers in various ways: the lights can be used in windy or rainy conditions, the catch is no longer at risk of contamination from kerosene spills and the accidental burning of traps is no longer a possibility. All these effects contribute to reducing poverty levels for the fishermen's families.

RESULTS & IMPACT

In total, kerosene lamps used by 504 canoe fishermen and 50 Ja-Kotu systems were replaced by efficient lamps. The resultant decrease in kerosene use amounted to 200,000 litres per year and CO_2 emissions were reduced by 600 tonnes per year. Additionally, the local ecosystem benefits from the switch to sustainable lighting systems. From a social perspective 850 households (or about 4000 people) have improved their standard of living – and this does not include the indirect beneficiaries (e.g. fish traders). The six service centres in the project area contribute to

the sustainability of the development by supporting the fishermen in the use of efficient lamps.

REPLICABILITY

The potential to replicate the measures undertaken in the project is very good. 85,000 canoe fishermen operate in the southern coastal water bodies of Sri Lanka, burning more than 100,000 litres of kerosene per night (equivalent to between 18 and 30 million litres per year). This fossil fuel use has been significantly reduced by the introduction of efficient lamps. The project helped to raise awareness among local and national politicians, media representatives and the population about the many advantages of efficient lamps.

LESSONS LEARNED

To make the lighting system 100% environmentally sustainable the batteries would have to be charged using renewable energy. Therefore sixteen solar photovoltaic systems were installed for testing and demonstrating purposes. However, as the electricity from the grid is highly subsidised in Sri Lanka and photovoltaic energy is still relatively expensive and has high initial investment costs, this solution was not economically feasible. Despite this drawback, using grid electricity to charge the batteries is an economic solution that reduces CO_2 emissions and helps to alleviate the poverty of local fishermen.

Source: Final Report submitted to WISIONS by Global Nature Fund

LIGHTING OUTDOOR SPACES

The provision of good levels of outdoor lighting in public (and private) areas during the night is one of the basic lighting services in modern life. Outdoor lighting covers a broad range of applications such as public street lighting, parking places, sport facilities, commercial outdoor lights or "city beautification". Around 8% of the global power consumption for lighting services in 2005 was attributable to street lighting [2].

Although regarded as a basic service, the adverse impacts of outdoor lighting (i.e. light pollution) increasingly attract criticism. There are a number of different impacts, of which the main examples are:

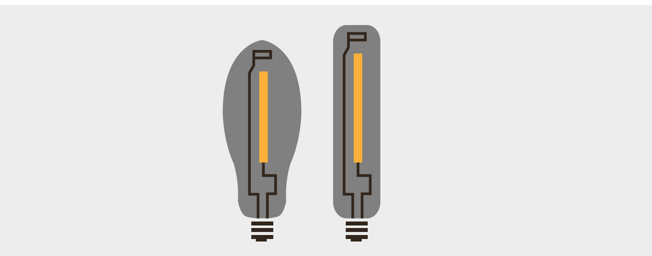
- Inappropriate system design resulting in light intrusion into bedrooms in residential buildings.
- Artificial sky glow blocking the view of the night sky.
- Artificial lighting at night altering natural light regimes of contiguous ecosystems.

Some technical options, such as the appropriate design of luminaries or the use of dimming controls during "off-peak" times, may help to lessen (at least to some extent) the undesired effects.

There is still significant scope for reducing the energy consumption of street lighting and other outdoor applications. The most immediate measures comprise the substitution of inefficient mercury vapour lamps and inefficient ballast by lamps and ballasts with higher energy efficiency. The next sections describe two concrete technical options that can contribute to that aim:

1. The use of sodium vapour lamps
2. Selecting adequate ballasts and controls

SODIUM VAPOUR LAMPS



In sodium vapour lamps light is emitted when an electrical discharge is produced within a translucent or transparent tube filled with a gas containing solid sodium. Sodium vapour lamps are highly effective. The spectrum of the emitted light is, however, very poor so they are mainly applied for external lighting

(e.g. public street lighting and outside industrial facilities). There are two types of sodium vapour lamps, low and high pressure.

- **Low-pressure sodium vapour lamps**

The low-pressure sodium (LPS) vapour lamps achieve the highest luminous efficacy among commercial lamps, up to 200 lm/W. They emit a soft luminous glow, which results in less glare. The light output is virtually constant during the whole life cycle, which can reach up to 18,000 hours. They require a short warming phase before reaching full light output. The main disadvantage of this kind of lamp is that the light produced is virtually monochromatic, a bright orange-yellow. LPS lamps are available for power ranges of between 10 W and 180 W

- **High-pressure sodium vapour lamps**

High-pressure sodium (HPS) vapour lamps achieve luminous efficacy of between 70 and 140 lm/W. These figures are lower than the low-pressure sodium lamps, but still represent one of the highest levels among commercial lamps. High-pressure sodium lamps emit light with a broader spectrum than the light emitted from low-pressure lamps, but the spectrum is still poor in comparison to other kind of lamps. HPS lamps can be found for wattages up to 250 W or even higher. They require warming periods of several minutes before reaching full light output. Once turned off, HPS lamps must cool down before being relit.

Environmental issues

Artificial light attracts a variety of insects that are active during the night. However, the spectral sensitivity of insects is different to that of the human eye and insects do not react to the orange/red part of the spectrum. The poor spectrum of sodium vapour lamps is less attractive than that of other conventional lamps, and can be an advantage when used outdoors.

Social issues

Mercury vapour HID lighting is an outdated technology that is much less effective and more expensive to operate over its lifespan than its competitors (sodium and metal halide HID lamps); nonetheless, it continues to be widely used for outdoor public lighting because it is comparatively cheap to purchase and install at the outset.

Many local authorities are either unaware of the life-cycle cost and quality advantages of alternative technologies or have perverse cost-management incentive structures that reward lowest cost capital procurement to the detriment of operating costs. The inability of many local authorities to finance capital investment projects is also a constraint that limits the uptake of higher-efficiency options.

Development status and prospects

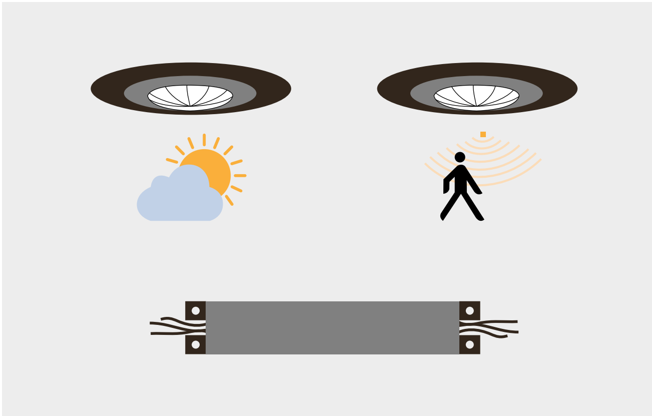
Both types of sodium vapour lamps have been commercial available for many decades.

Economic issues

Street lighting systems that are more energy efficient require greater initial investment than the less efficient options. Firstly, sodium vapour lamps can be twice the market price (or even more) in comparison to mercury vapour lamps [9]. Additionally, only opting for lamps with higher luminous efficacy does not directly translate into less energy consumption. Selecting appropriate ballasts (e.g. lower power ratings or electronically dimmable ballasts) are also required in order to actually achieve energy savings.

However, total life-cycle costs (i.e. including costs for energy, maintenance and replacement) of improved street lighting systems can be between 15% to 30% lower than conventional systems that use mercury vapour lamps [9].

BALLAST AND LIGHTING CONTROLS



Ballast and lighting controls are used to regulate the power supply to the lamp, which in turn has a significant effect on the overall performance of the lamp. Special attention should be taken when retrofitting old systems using mercury vapour lamps. The ballasts of such systems provide a fixed power output. Replacing only the lamps would probably lead to the same consumption of electricity but with higher light output, as sodium vapour lamps have higher luminous efficacy. Thus, retrofitting measures should also incorporate the replacement of ballasts by more appropriate ones. Additionally, the energy efficiency of the system can be improved by applying lighting control strategies, e.g. dimming street lights when the traffic flow is extremely low, as illustrated by Case Study 7 in this publication.

CASE STUDY 7

IMPROVING THE ENERGY EFFICIENCY OF CITY STREET LIGHTING IN INDIA

PROJECT'S AIM

To demonstrate the energy saving potential of city street lighting by retrofitting a part of the existing system.

PROJECT DESCRIPTION

Traditionally, city street lighting in India has not been designed, operated or maintained very efficiently. As a result, the energy consumption for city street lighting in India is very high. Efficient lighting technology was not a viable option in the past because it had to be imported and was expensive, but new energy efficient lighting equipment and good controls are now available on the Indian market. Consequently, the main objective of this project was to demonstrate the energy saving potentials of the city street lighting system. By retrofitting parts of the existing system with more efficient components, it would be possible to estimate the potential GHG reduction.

The Energy and Resources Institute (TERI) implemented the project in collaboration with the Pune municipal corporation (PMC). The project comprised a number of different activities, starting with the collection of data about the existing city street lighting systems in Pune. The combined team of TERI and PMC surveyed various streets and different stretches of road were identified as project sites. In the next step, the optimal lighting schemes were chosen. Using computer simulation tools, the schemes were designed to meet the lighting requirements as per Indian standards. The next stage was to organise a manufacturer's meeting at PMC. Manufacturers of lighting fixtures were invited and briefed about the project and information about the most efficient fixtures and controls was shared. After deciding which technology should be used, the necessary equipment was procured and installed.

Location:
Pune, India

Costs:
Total: € 94,000
WISIONS financial support: € 40,400

CO_2 Reduction:
Potential energy savings for total outdoor lighting sector in Pune 27.7. kt CO_2/year

Partners Involved:
The Energy and Resources Institute (TERI) (www.teriin.org)

Implementation Phase:
06/2006 - 10/2009 (with interruptions)

TECHNOLOGY, OPERATIONS AND MAINTENANCE

The existing systems in Pune generally use 70W, 150W and 250W high-pressure sodium lamps (HPSV) that are fitted into inefficient luminaries without automatic daylight controls. One of the most important factors of the new design was that energy consumption would be kept to a minimum. From the perspective of energy efficiency, the optimal combination of efficient luminaries would have been an arrangement of carefully selected overhang, mounting height and tilt angle luminaries. These would have to be arranged in such a way that poles are installed at the maximum spacing distances, so reducing the connected or operating load without compromising the lighting design requirements. However, as the project was a retrofit as opposed to a new installation, it would have been unrealistic to change the pole height and pole spacing as PMC would have had to uproot all the poles, disconnect all the wiring and feeder pillars and then install new poles and lay new electric wiring through new or existing feeder pillars. So PMC clearly stated that they wanted to improve the energy efficiency of the city lighting system but without changing the existing poles. Because of this, high-pressure sodium vapour lamps were selected to optimise the lighting system.

In the retrofit, 250W HPSV lamps with 33,000 lumen were used to replace the existing 250W fixtures and 150W HPSV lamps, which give 17,500 lumen output, were used to replace the existing 150W fixtures. The newly installed HPSV lamps are much more efficient compared to the existing HPSV lamps. All installed fixtures were also fitted with multi-tab ballasts, enabling a fixture fitted with 250W lamps to operate both at 250W and 150W. Lighting controls with daylight sensors were also installed, meaning that the lights can be automatically controlled according to seasonal variations.

FINANCIAL ISSUES AND MANAGEMENT

The existing city lighting load in Pune is approximately 20kW per km of road. With the sustainable city lighting system it would be reduced to 7kW per km. This would save approximately € 3,200 per km per year. Retrofitting would cost about € 10,500 per km so the payback period would be about 3.3 years. This proves that retrofitting street lighting systems is an attractive option for PMC and other local development authorities.

During this pilot project TERI acted as the technical expert and project manager, with PMC as the primary stakeholder and agency responsible for the implementation. For future projects the toughest challenge will be to bring the various stakeholders together in such a way that they take on joint ownership of the venture.

ENVIRONMENTAL ISSUES

Public lighting accounts for only 1% of India's total electricity consumption. However, according to available data, electricity consumption for public lighting systems is increasing at a rate of 10% (compared to an overall increase in India's electricty consumption of 7%).

The actual consumption for public lighting in India is 7,753GWh. With an estimated energy saving potential of 30% through efficiency improvements 2,326GWh of electricity could be saved. This means that CO_2 emissions could be reduced by as much as 1.9 million tonnes annually. In Pune the saving potential in the public lighting sector is estimated to be 27.7 million kg CO_2/year.

SOCIAL ISSUES

Enhanced street lighting improves the traffic safety. Furthermore, the cost savings made by improving the public lighting systems mean that money would be available for the local authority to use for other purposes e.g. in the health or education sector.

RESULTS & IMPACT

The installation of the energy efficient street lighting system has been successfully completed on different sample road stretches in the city of Pune. It has demonstrated that there is an energy saving potential of about 30% for city street lighting in India.

In total, 500 inefficient fixtures were replaced with more efficient fixtures and fitted with more efficient lamps. These fixtures have multi-tab ballasts so that after midnight, when traffic reduces on Indian roads, the fixtures can be dimmed. After the retrofit, the lighting levels were better - both in normal and dimmed modes.

In order to share the lessons learned from the completed demonstration project in Pune, a Handbook on Street Lighting has been published. The handbook explains in detail every stage of the project, illustrates technological solutions, highlights energy and cost saving potentials and recommends a financial model. The handbook offers guidance in the design and implementation of energy efficient street lighting systems in India.

REPLICABILITY

The potential for replication in India is very good, as currently nearly all public lighting systems are very inefficient. The main constraints for replication are local authorities' lack of technical expertise and their lack of finance. To overcome the financial constraints, TERI has evolved different financing strategies, which could help replicate energy-efficient city street lighting solutions. The proposed strategies include energy service companies, financial institutions and the local development authority, because the key for long-term viability and replicability is to involve all stakeholders.

During the project TERI also developed an optimised lighting design for Indian carriageway widths taking into account Indian standards. This could be very helpful to local authorities and other organisations that want to establish efficient street lighting schemes in India.

LESSONS LEARNED

Financial companies and private energy service companies (ESCOs) are not very keen on working with local authorities, because government organisations have a poor track record in developing such projects with ESCOs. To overcome this, TERI decided to bring all stakeholders together in a workshop to find a solution to speed up the development of energy efficient street lighting in India.

Source: Final Report submitted to WISIONS by TERI

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