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LIGHTING TECHNOLOGY

Electric lighting accounts for around one-fifth of electricity consumption, both in the UK and globally. Under recent legislation, the traditional incandescent lamp is being phased out in the UK, saving 1 million tonnes of carbon dioxide a year by 2020 (equivalent to the emissions of around 180,000 households today). This POSTnote gives an overview of energy efficient lighting currently available and under development. It examines policy initiatives to drive uptake, as well as relevant health, environmental, public perception and economic issues.

Background

The global demand for artificial lighting is predicted to be 80% higher by 2030.[1] Furthermore, the global carbon dioxide emissions from electric lighting are already three times greater than those from the entire aviation sector. The Government's Energy White Paper *Meeting the Energy Challenge* published in May 2007 and *UK Low Carbon Transition Plan* published in July 2009, emphasise the key role for greater energy efficiency in reducing carbon dioxide emissions and ensuring energy security.[2,3]

Electricity consumption by lighting in the UK is split between the commercial (70%), residential (26%) and street lighting (4%) sectors according to the estimates of the Department for Environment, Food and Rural Affairs (Defra). Commercial lighting is often already more efficient than residential lighting, but emerging technologies have the potential to provide energy savings across all sectors. According to the International Energy Agency, at least 38% of global electricity consumption from lighting could be saved by adoption of energy efficient lighting.[4]

Lighting Systems

Electric lighting systems consist of a *luminaire* (or fixture) that contains a *lamp* (or light bulb) to convert electrical energy to visible light (Box 1) and often additional electronic components. They also contain *controls*, which range from a simple switch to light, motion and other sensors.

Box 1. Electric Lamps

Electric lamps vary in their energy efficiency (see Table 1), durability, intensity and colour output, as well as shape and size. They can be grouped into five categories.

- **Incandescent:** produce light by passing electricity through a thin tungsten filament. Traditionally used for residential lighting, but inefficient. They include the halogen lamps that have become popular for lighting residential kitchens and bathrooms.

- **Discharge:** produce light by passing electricity through a gas. Suitable for providing high levels of light for large areas such as warehouses, and for street lighting. Efficiencies can be very high, but may lead to poor quality orange or yellow light.

- **Fluorescent:** a type of discharge lamp that emits ultraviolet light, which is converted to visible light by a coating. Compact Fluorescent Lamps (CFLs), often called 'energy saving' lamps, are designed standard fittings. As with other discharge lamps a warm-up period is required to reach full brightness.

- **Light-Emitting Diode (LED):** the light emitting material in LEDs consists of a metal alloy, or in the case of Organic LEDs (OLEDs), a carbon-based material. Varying the material results in a different colour of light.

- **Induction:** specialist lamps that use wireless technology. This increases both lifetime and purchase cost.


Images: Lighting Industry Federation

Character, Quality and Colour of Light

The character of light is determined by both lamp selection and luminaire design. White light is described using a temperature scale: 'warm' light is yellowish-white, whereas 'cool' light is blueish-white. People are highly sensitive to colour temperature as the changes in sunlight throughout the day help to regulate circadian rhythms. Typically, warm light is used to aid relaxation, for example in the home, whereas cold light is used to aid concentration, such as in offices. White light is increasingly being used for street lighting as it enables improved visual perception and colour reproduction over the orange or yellow light emitted by some discharge lamps.

Energy Efficiency and Lifetime

Carbon dioxide is emitted during raw material production, manufacturing, and distribution of lighting products (so-called 'embodied carbon'), as well as during their operation. Research indicates that the energy consumed by lighting during use accounts for the majority of consumption over the lifechain.[5] The energy efficiency and lifetime of a lighting system is dependent on both the luminaire design and electronics, as well as the lamp used. The lamp's energy efficiency is determined by the ratio of light emitted (in lumens) to electricity consumption (in Watts), and decreases as it ages.

Table 1. Energy Efficiencies and Lifetimes of Lamps[6]

Lamp Technology	Energy Efficiency (lumens per Watt)	Typical Lifetime (hours)
Incandescent	8-14	400-2,000
Halogen Incandescent	15-25	1,500-5,000
Fluorescent (tube)	45-100	6,000-70,000
Fluorescent (CFL)	50-70	3,000-15,000
LED	50-100	20,000-50,000
Discharge	60-130	15,000-20,000
Induction	50-70	>60,000

The lighting industry claims that lamps designed for retrofitting into existing fixtures have a shorter lifetime than those integrated into a dedicated luminaire. This increases the environmental impact of manufacture and disposal.

High Efficiency Lighting

Highly energy efficient technologies that produce high-quality white light include modern fluorescent tubes, some discharge lamps and Light Emitting Diodes (LEDs) (Box 2). LED lighting has the potential to replace fuel-based lighting in the developing world (Box 4).

Box 2. LED Lighting

LEDs offer the potential for highly efficient lighting that can last for more than a decade of continuous use. To achieve such long lifetimes, specially designed luminaires are necessary. Mixing red, green and blue LEDs can be used to generate 'tuneable' coloured light for mood lighting or mimicking daylight. Alternatively, white light can be generated using blue LEDs and a coating. At present the energy efficiency of LEDs is similar to, or lower than, that of modern fluorescent tubes or discharge lamps. There is a consensus among industrial and academic experts that this will continue to improve, whereas that of fluorescent lamps is unlikely to do so at the same pace due to technical limitations. Experts predict the gradual adoption of LED lighting over the next 5-10 years as costs fall. The market for LED lighting is predicted to grow by 22% annually from 2009-2013 according to the Department for Business, Innovation and Skills (BIS).[7]

Organic LED (OLED) technology is currently used in TVs and mobile phone screens. Unlike conventional LEDs, it can be used to generate thin panels of light but energy efficiency, lifetime and cost lag behind conventional LEDs at present. Processes to print OLEDs onto rolls of flexible material are being developed, although it is unclear if this will be commercially viable on a manufacturing scale.

Smart Lighting Systems

Smart lighting systems combine high efficiency lighting with controls. This allows the level of lighting to be adjusted according to demand and environmental conditions (Box 3). The wider use of control systems is seen by many in the lighting industry to offer an "easy win" for energy efficiency gains. The technology is mature and payback times are typically short. Lighting controls have yet to penetrate the consumer market significantly, primarily due to their expense, yet the ubiquity of wireless communications devices may provide opportunities for remote control through devices such as mobile phones.

Box 3. The Westminster Smart Lights Initiative

Westminster City Council is responsible for around 14,000 street lights, producing an annual electricity bill of nearly £1m. The Smart Lights initiative aims to reduce electricity consumption by 20% by installing energy efficient luminaires and a system that allows the remote control and monitoring of individual lights. The system allows the lighting to be adjusted according to demand, for example lighting is increased outside theatres before and after performances. The use of LED lamps is also being trialled, providing the potential for further energy savings and coloured mood lighting. Westminster City Council estimates that the scheme will pay back in seven years and aims to extend it throughout the borough.

Lighting Research and Development in the UK

The global demand for lighting fixtures was estimated to be in excess of $91 billion in 2007. The Department for Business, Innovation and Skills (BIS) is responsible for promoting the UK lighting industry. It also provides research and development funding through the Technology Strategy Board and the Engineering and Physical Sciences Research Council (EPSRC). The EPSRC funds approximately £37 million worth of research into LED and OLED devices. The UK has over 1,700 companies working in the lighting industry and its supply chain. World class research into white light LEDs is being conducted, in particular at Cambridge University. UK-based small and medium sized companies involved in manufacturing LED lighting products are however reliant on overseas suppliers due to a lack of domestic producers of some components. The UK is considered a world leader in OLED technology, with academic and industrial expertise in materials research and manufacturing. Initiatives include a collaborative project between Thorn Lighting, Cambridge Display Technology and Durham University to develop this technology commercially.

Box 4. Lighting for the Developing World

At present, 1.7 billion people do not have access to electric light, but rely on kerosene lanterns or other fuel-based lighting.[8] Not only is fuel-based lighting more costly than its electric counterpart, it is inefficient, provides poor quality light and poses a health and fire risk. LEDs are well suited to replacing fuel based lighting as they are long lasting and require little power. They can be powered by solar panels, so are suitable for 'off-grid' use in rural or developing areas. The World Bank's Lighting Africa Initiative supports the private sector in developing and sustaining the market for off-grid lighting. It aims to provide electric lighting for up to 250 million people in Sub-Saharan Africa by 2030.

Policy Initiatives

The government is promoting the uptake of energy efficient lighting through numerous energy efficiency initiatives:[9]

- the Department of Energy and Climate Change (DECC) leads on reducing carbon dioxide emissions;
- Defra's Market Transformation Programme supports policy relating to energy using products;
- part L of the Building Regulations (2006) requires a certain proportion of lighting in newly built premises to meet minimum energy efficiency levels. This will be revised in 2010.

Energy-Using Products (EuP) Directive

The EU Eco-design for Energy Using Products (EuPs) Directive sets requirements for energy-using products. For lighting this includes the phase-out of incandescent lamps (Box 5). In the UK this has been accelerated by a voluntary retailer-led initiative to remove incandescent bulbs from sale by December 2011.

Box 5. EuP Directive Implementing Measures

Implementing Measures (IMs) under the Directive set minimum energy efficiency and performance measures for non-directional household lamps and for office and street lighting. These include:

- the phase-out of incandescent lamps between September 2009 and September 2012;
- standards on performance, lifetime and ultraviolet light emission for CFLs from September 2009;
- the phase-out of low efficiency fluorescent tubes and electronics between April 2010 and April 2017.

A further IM covering directional household lamps, including halogen spot-lights and LEDs, is expected in 2010.

Other countries including Australia, Brazil, Canada, Russia and the USA are phasing out incandescent bulbs between 2009 and 2014, which the International Energy Agency regards as the first priority for improving the energy efficiency of lighting. Intellect (the UK technology industry's trade association) is supportive of the Directive, as it "levels the playing field" for companies that invest in developing energy-efficient products.

The National Measurements Office assumed responsibility for enforcement from local Trading Standards officers in October 2009. At present the sanctions for non-compliance are limited to a criminal conviction and a maximum fine of £5,000. Following consultation, the government has stated its intention to introduce a broader range of penalties for non-compliance. Research by Defra's Market Transformation Programme suggests that at least 25% of energy-using products do not perform as claimed, therefore non-compliance by manufacturers is likely to be widespread.

Public Procurement

The Government's *UK Low Carbon Transition Plan* highlights the potential for public sector demonstration projects to accelerate the uptake of ultra-efficient lighting (Box 6).[3] Organisations such as the Energy Saving Trust (EST) and Technology Strategy Board, as well as academic and industrial experts, are in agreement, but some believe that more comprehensive initiatives are required than those presently being undertaken. Central government departments are required to buy lighting that meets minimum energy efficiency standards set by Defra.

Box 6. Public Procurement and Lighting

Two programs exist within the government to stimulate innovation through public procurement.

- The *Forward Commitment Procurement* model provides a commitment to buy an innovative product that is still under development if it meets a certain specification. The Rotherham Foundation NHS Trust, with support from BIS and the Department of Health, is using this model to develop a £2 million high efficiency lighting system for hospital wards.
- The *Small Business Research Initiative* is a competition-based programme to solve a challenge submitted by a government department. Successful applicants are awarded contracts to demonstrate feasibility. If successful, further funds are provided for product development.

Product Labelling Schemes

Product labelling schemes aim to inform consumers about the energy efficiency of residential lighting products. Labelling schemes used in the UK include:

- the *EU Energy Labelling Directive*, a mandatory scheme requiring the packaging of lamps (light bulbs) sold to the residential sector to display an energy efficiency ranking between A (highest) and G (lowest). Other information that must be displayed includes light output in lumens and average lifetime. At present this does not cover directional lighting, such as halogen lamps and LEDs;
- the EST's *Energy Saving Recommended* logo is awarded to household products that are tested and considered "best in class" (within the top 20%). The criteria include quality of light, lifetime and energy efficiency. Some lamp manufacturers use standardised packaging across Europe, so choose not to display the logo. Certified products are listed on the EST website;
- the EU *Eco-Label* logo is a voluntary Europe-wide scheme for products that meet specific energy efficiency and quality specifications.

Incentive Schemes

Initiatives providing a financial incentive for the installation of energy efficient lighting include:

- the *Carbon Emissions Reduction Target*, which requires large energy suppliers to reduce household carbon emissions. Nearly 182 million Compact Fluorescent Lamps (CFLs) had been mailed out under the scheme by November 2009 (an average of eight per household).[10] This has been prohibited since January 2010 due to concerns that they are often not used. The EST believes that extending the scheme to subsidise LEDs would drive the market for this technology;
- the *Enhanced Capital Allowance* scheme allows businesses to claim 100% tax relief on qualifying high efficiency lighting systems and lighting controls;
- The Carbon Trust provides loans for commercial and public sector bodies to install highly efficient lighting.

Issues

Environmental Impact

Fluorescent tubes, CFLs and some discharge lamps contain a small quantity of mercury, a substance restricted under the European Restriction of Hazardous Substances Directive. Defra has concluded that over its lifetime, a CFL causes less mercury to be released into the environment than an incandescent bulb (mercury is released from burning fossil fuels). Nonetheless, there is potential for localised mercury release from broken lamps (for example in landfill sites). The Health Protection Agency (HPA) does not consider a single broken CFL indoors to pose a health risk. CFLs are covered under the Waste Electrical and Electronic Equipment (WEEE) regulations, which require producers and retailers to take responsibility for their electronic products once they are no longer required (Box 7).[11]

Box 7. Waste Electrical and Electronic Equipment
Lighting retailers usually meet their WEEE obligations by funding collection points at recycling centres; however, some believe that well-publicised retailer take-back schemes such as those run by IKEA and Sainsbury's are necessary to improve compliance with the WEEE Directive.

Lighting and Health

Ultraviolet Exposure

All fluorescent lamps convert UV light to visible light. Groups representing photosensitive individuals are concerned that CFLs have the potential to exacerbate certain skin conditions. Preliminary studies by the HPA and the University of Dundee concluded that UV emissions from CFLs could exceed recommended levels at close proximity to the skin (for example in desk lights).[12,13] This is considered unlikely to pose a risk to the general population, but could potentially be harmful to those suffering from conditions such as chronic actinic dermatitis and lupus. Both studies found that the use of "incandescent look-a-like" CFLs that contain an extra glass coating would mitigate this risk, an opinion endorsed by a European Commission scientific committee.[14] The HPA advises that standard CFLs should not be used in close proximity (less than 30 cm) for more than one hour per day.[15]

Flicker

Flickering lighting is linked with conditions including eyestrain and headaches. Incandescent bulbs do not flicker significantly, whereas discharge, fluorescent and LED lamps require electronics to suppress flicker. Preliminary research by the HPA has indicated that significant numbers of CFLs flicker, potentially leading to adverse effects.[12]

Current advice is based on preliminary studies involving a small number of individuals. Consequently, some academics believe that further research is necessary.

Barriers to Uptake

Public Perception

The uptake of CFLs has historically been limited by their poor performance and bulky design. Modern CFLs have largely solved these issues, yet public attitudes are influenced by these perceived limitations. The Lighting Industry Federation believes that this may have been heightened by the mail-out of low specification lamps. The Energy Saving Trust, Carbon Trust and several companies have expressed concern that this situation could be repeated for LEDs, as many commercial products are sub-standard. No domestic LEDs have received Energy Saving Recommended status to date.

Economic Factors

So-called "split incentives" – the reluctance of developers or landlords to invest in lighting when the occupants are responsible for energy costs – are a further barrier. Philips Lighting advocates greater dialogue between developers and end-users, for example the installation of several small-scale demonstration projects from which a client could choose a suitable lighting scheme.

Burden of Compliance

Individual policy initiatives and pieces of legislation apply different technical metrics to define energy efficient lighting. The Carbon Trust believes that harmonising these disparate approaches would be advantageous.

Overview

- Lighting accounts for around one-fifth of electricity consumption and demand is growing.
- Retrofitting inefficient lighting with alternative technologies would lead to a significant reduction in carbon emissions. Many of these are already available.
- Policy initiatives include legislation, incentives, consumer education and public procurement schemes.
- The performance, safety and environmental impact of lighting must be considered in addition to energy efficiency.

Endnotes

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POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of public policy issues that have a basis in science and technology. POST is grateful to Richard Gunn for researching this briefing, to the EPSRC for funding his parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Dr Martin Griffiths, at POST.

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