Solstice

High-Efficiency Lighting in Industry and Commercial Buildings

by **Brian Cook**
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The amount of energy used from lighting varies from industry to industry, but typically, lighting accounts for approximately 15% of the electrical load in industry. In offices, the lighting may account for 50% of the electrical load. By having an understanding of the lamps, ballasts, luminaires and control options available today as well as the techniques used to develop efficient lighting, lighting can be produced that is energy efficient, cost effective and yields a higher quality of light.

Table of Contents

Introduction

In recent years there have been many new developments in the lighting industry, in both technological equipment and approaches to lighting design. The developments in lamp technology have led to lamps yielding higher efficiency, improved colour rendering and longer lives. Developments in electronic ballasts have produced ballasts that provide discharge/fluorescent lamps with flicker-free operation, longer life, faster run-up time and cooler operation; in addition, some units provide smooth and silent dimming. There has also been many developments in electronic controls for lighting, either daylight linked or occupancy linked.

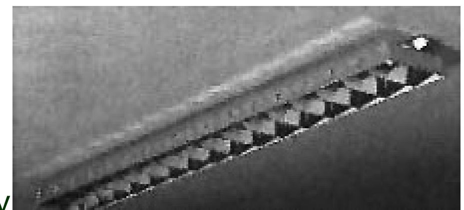

Fig.1 High-efficiency specular reflector.

One result of these technological developments in the lighting industry has been the improvement potential in lighting efficiency, thus a reduction in energy consumption and costs. In many cases electricity costs for lighting have been reduced by 65% or more (see later case studies). The simple payback for the costs of a lighting upgrade is typically between 1 and 3 years.

The additional result of the these developments in lighting has been the improvement in the quality of light available, as introduced above. Through improving the quality of light in an industry or commercial building, there is often an increased productivity, due to better working conditions in the building or plant.

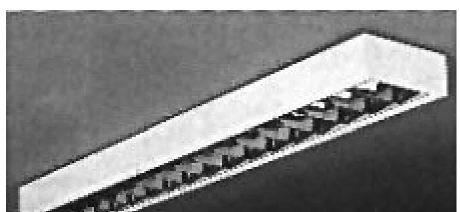

Fig.2 High-efficiency luminaire.

Improvements in lighting efficiency can be obtained in seven distinct areas:

1. Lamps - replacing inefficient lamps with the most efficient lamp for the purpose, taking into account size, shape, colour and output of the lamp.
2. Ballasts - replacing standard choke ballasts with high frequency electronic ballasts.
3. Luminaires - retrofitting standard luminaires with high-efficiency specular reflectors or replacing standard luminaires with high-efficiency luminaires.
4. Automatic control systems - installation of (a) timer circuits that switch lamps off during room vacancy times, (b) photoelectric sensors that sense the amount of daylight in the room and either switch lamps on or off or adjust the lamp brightness accordingly and (c) occupancy sensors that switch lamps off when work stations are unoccupied.
5. Localized switching - installing localized switches near work

stations to control local lighting.
6. Lighting design - (a) designing lighting systems that maximize the use of daylight, such as the PSALI system (permanant supplementary artificial lighting in interiors) and (b) introducing local task lights (e.g. desks lights), allowing a reduction in general overhead lighting.
7. Maintenance schedule - setting up a maintenance schedule to clean and replace lamps on a regular basis.

This article explores some of the recent developments in the lighting industry, with the focus on methods of improving the lighting efficiency and the quality of light in an industry or commercial building. Please see the pop-up window for **definitions** of terms used in this document.

Lamps

1. Compact fluorescent lamps

General lighting service (GLS) tungsten incandescent lamps are used primarily for local lighting and emergency use. They switch on and off instantly but have low efficacy. In locations where incandescent lamps are on for extended periods of time, they can be replaced with self-ballasted compact fluorescent lamps (CFL) of similar brightness. Compact fluorescent lamps have approximately five times the efficacy to that of tungsten incandescent lamps. They are available with the same socket configuration as an incandescent lamp, so they are interchangable. Compact fluorescent lamps are available in various shades of white, the most common ones being:

- extra-warm white (2700 K)
- warm white (3000 K)
- white (3500 K)
- cool white (4000 K)

While the 'extra-warm white' closely matches the colour of an incandescent lamp, the lamps with a higher colour temperature have a higher blue content and thus appear cooler. Compact fluorescent lamps are also available in an improved colour series, commonly called 'de luxe'. The de luxe series was designed to produce a higher colour rendering ability by using a multiphosphor coating rather than the standard single phosphor coating. Thus, in locations where colour rendering ability is critical, the de luxe series (or improved colour series) are used, however there is a reduction in light output of 34-37%, depending on the particular lamp. The purchase cost of a compact fluorescent lamp is higher than the purchase cost of an incandescent lamp, but the compact fluorescent lamps produced today have an average life of 12,000 hours, versus 1000 hours for a standard incandescent lamp (2000 hours for a long-life incandescent lamp).

The power factor of a self-ballasted CFL is typically around 0.5, due to harmonic distortion added to the circuit from the ballast. The phase displacement between the supply voltage and the fundamental component of the current typically has a cos q = 0.95 or higher. However, due to the phase displacement of the harmonics, the effective cos q can be as low as 0.5.

As the low power factor is due to harmonic distortion and not a displacement of the fundamental component of the current, it cannot be corrected with power factor correction capacitors. In large installations of CFLs the effect of harmonic distortion needs to be taken into consideration. Electronically ballasted adaptors are available in some countries, designed to give high power factors of 0.8 or more. With CFLs that are not self-ballasted this creates no problem, as independent electronic ballasts are available which give power factors in the range of 0.96 - 0.99. **Table 1** summarizes the efficacy, average life and color rendering of the various lamps presented in this article.

2. Tungsten halogen lamps

Conventional incandescent lamps lose filament material by evaporation, most of the material being deposited on the bulb wall. In a tungsten halogen bulb, halogen (iodine, bromine or florine) is added to the filling gas. If the correct temperatures are met, the discharged tungsten molecules from the filament will combine with the halogen molecules in the gas. The newly formed tungsten halogen molecules diffuse towards the filament, the tungsten being deposited back onto the filament, while the halogen is available for a further cycle. This regenerative cycle keeps the bulb clear for the entire life of the lamp. Higher gas pressures are used in the lamps, which minimizes tungsten evaporation, thereby improving the overall quality of the lamp. The colour of a tungsten halogen lamp (2900-3100 K) is slightly whiter than that of a standard incandescent lamp. Tungsten halogen lamps have virtually replaced larger output incandescent lamps because of their higher efficacy (+15%), compact size, improved clarity and longer life.

3. Fluorescent lamps

For general-purpose lighting, in low mount situations (below 6 metres), fluorescent lamps are most commonly used. They are not suitable though for cold locations, such as refrigerated storage areas, as the light output of a fluorescent lamp decreases with a decrease in ambient temperature. In general, fluorescent lamps produce peak light output at a temperature of approximately 25°C. At 0°C, 26 mm diameter (T8) lamps have a light output of approximately 50%, while 38 mm diameter (T12) lamps have a light output of approximately 80%, dropping to 50% output at approximately -8°C.

Fluorescent lamps are available in a variety of wattages and colours.

They are economical, cool in operation and have high efficacy. There has also been, in recent years, many advances in the development of more efficient fluorescent lamps, through the introduction of new gases and new phosphor combinations. These lamps offer an improved efficacy and higher colour rendering than standard fluorescent lamps, and are thus available in reduced wattages, producing equivalent outputs of light.

There are two different types of energy efficient lamps, those using tubes filled with standard argon-gas and those using tubes filled with a mixture of argon and krypton gas. The first type uses standard argon gas in a reduced diameter tube (i.e. 26 mm, T8 instead of standard 38 mm, T12 tube), but requires an electronic, high-frequency ballast to operate it. The second type uses a mixture of argon and krypton gas (80% argon, 20% krypton) in a reduced diameter tube. These lamps have the advantage that they will operate from a standard choke ballast and can therefore be used as direct replacements for standard lamps. Comparing a 36 watt, reduced diameter krypton lamp with a 40 watt standard lamp, the 36 watt krypton lamp has an improved power factor of 7% and the voltage drop across the lamp is reduced by 3%, thus a reduction of active power by 10%.

Energy efficient lamps have a reduced wattage of 10 - 20%, depending on the particular lamp, with little or no reduction of light. In addition to the energy saving, the reduced diameter tubes require less phosphor coating on the surface of the tube, thus less phosphors are required in the making of the tube.

Fluorescent lamps, whether argon-filled or krypton-filled are available with several different tube coatings:

- standard coatings (warm white, white, cool white)
- improved colour coatings (de luxe series, natural, artificial daylight)
- narrow-band triphosphor coatings (SP series from GE, Lumilux series from OSRAM)

Standard coating lamps use single halophosphate phosphors. This produces lamps with a moderately high efficacy, but while producing an acceptable white light, they are not recommended for areas where critical colour is a concern. Standard lamps have an Ra between 54 and 67 (Ra 54 for warm white, Ra 67 for cool white).

Improved colour lamps are created by blending together several different halophosphate phosphors that each cover different regions of the spectrum. The result is a lamp with a much higher colour rendering ability (Ra 93-98), but a lower efficacy (typically a reduction in light output of approximately 30%, depending on the wattage).

Triphosphor lamps use a different principle. They offer a high output of light (12% to 15% higher than that of standard coating lamps) combined with a high colour rendering ability (Ra 85). They are made by combining together a thin layer of a conventional halophosphate phosphor with a thin layer of a triphosphor blend. A triphosphor blend is a combination of three narrow-band rare phosphors that reproduce the three primary colours of the spectrum, each with a very narrow bandwidth. Because of the very narrow bandwidth, the peaks are very high, thus these lamps produce a high output of light. The triphosphor lamp combines the high quality of the narrow-band rare phosphors with the economy of a conventional halophosphate coating. Triphosphor lamps are often quoted by their rounded-off colour temperature:

- 2700 K (extra-warm white)
- 3000 K (warm white)
- 3500 K (white)
- 4000 K (cool white)

By replacing standard lamps with energy-efficient, reduced-wattage lamps with triphosphor coatings, the energy consumption of the fluorescent lighting load can be reduced by 10% or more and the colour rendering ability of the lamps will be significantly improved. Some examples are shown in **Table 2.** Spectral characteristics of various lamps are shown in Fig. 3.

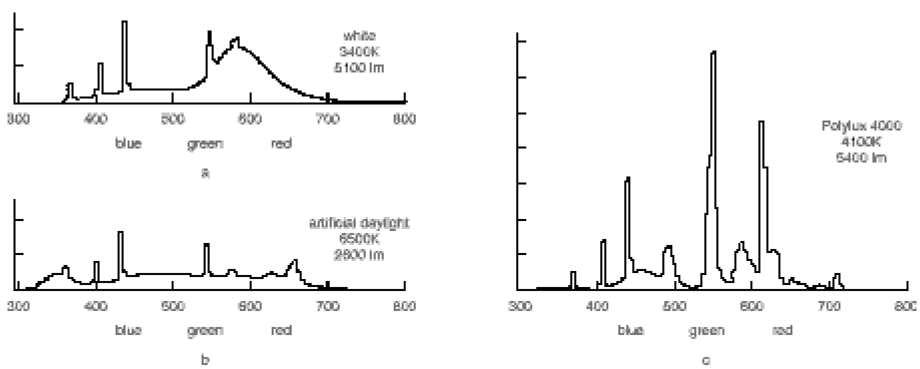

Fig.3
Spectral characteristics of various lamps:
(a) Standard coating (single halophosphate phosphor), 65 watt;
(b) Improved colour coating (multiple blend of halophosphate phosphors), 65 watt;
(c) Triphosphor coating (single halophosphate phosphor layer with narrow band triphosphor layer), 58 watt.

4. Low-pressure sodium lamps

Low-pressure sodium lamps have the highest efficacy of all lamps currently available and before the development of high-pressure sodium lamps, as already mentioned, were rapidly supplanting mercury discharge lamps. This refixturing is now larely restricted to areas where colour renditionis not important, as they emit a single frequency of light, a monochromatic yellow (wavelength 589nm). These lamps have an average life of 16,000 hours and require verylow maintenance. They are an ideal choice for outside areas such as parking lots or areas where securitylighting is required.

5. High-pressure sodium lamps

Prior to the 1970's colour corrected high-pressure mercury lamps were inevitably used for mounting heights above 6 metres and fluorescent lamps below 6 metres. Low-pressure sodium lamps were later introduced as a more efficacious option to mercury lamps for the higher mounting heights. They suffered from having a monochromatic spectrum and encouraged the development of high-pressure sodium lamps which provide a warmer yellow-orange colour (2100 K), yielding an Ra of approximately 25. Although of better colour-rendering ability than low-pressure sodium lamps they are not recommended for use in areas where colour rendition is critical.

High-pressure sodium lamps are now easily the most popular light source for new installations today and are available in a wide range of wattages from 50 to 1000 watts. These lamps require very low maintenance, some lamps having an average life of 30,000 hours. They are also available in an improved colour version (de luxe). The colour they produce is golden-yellow (2300 K) having an Ra of 60, but their efficacy is reduced by approximately 20%. Either of these lamps are highly recommended in large areas where high-efficiency and low maintenance are important and colour rendition is not critical. Retrofit lamps are available as direct replacements for existing mercury lamps. They are also increasingly being used for low mounting heights as well.

6. Metal-halide lamps

Metal-halide and high-pressure sodium lamps have virtually replaced mercury lamps today, because of their high efficacy and improved colour. Metal-halide lamps produce a bright white light (from 3000 K to 6000 K). They produce 50% more light than equivalent wattage mercury lamps and have a much higher colour rendering ability (metal-halide lamps have an Ra between 80 to as high as 93 for artificial daylight, versus an Ra of 44 to 49 for mercury lamps). Metal halide lamps are available in wattages from 175 to 1500 watts.

Metal halide lamps consist of a small tube (which contains the arc producing device) inside a larger glass bulb. Various halides (usually sodium, scandium and iodide) and mercury are placed inside the arc tube. When the lamps are burning, the halides and the mercury vaporise, producing the colour of the lamp. Depending on the particular combination of halides inside the lamps, various colours can be produced, from white to artificial daylight. In large areas where high-efficiency and colour rendition is important, metal halide lamps are highly recommended.

Retrofit metal halide lamps are available as direct replacements for existing mercury lamps. As they provide substantially more light output compared with the mercury lamps that they replace, the required wattages can be reduced.

7. Sodium-xenon lamps

A new sodium lamp has been recently introduced, designed for energy-saving. It has the capability to switch the lamp to approximately half output, which yields a power reduction of 31 or 35%, depending on the particular lamp. When full light output is not necessary, such as during the middle-of-the-night, use of this reduced-output option can save considerable energy. The lamp has a relatively high efficacy (65 or 74 lumens/watt), yet if used with the reduced-output option the net efficacy can be improved considerably higher.

The colour of the lamp (2800 K) is similar to that of an incandescent. It has a moderate colour rendering ability (Ra 45-50). These lamps require low maintenance as they have an average life of 15,000 hours and are ideal in locations where the warm colour of an incandescent is required, where colour rendering is not critical, but where high efficacy and low maintenance are important.

A sodium-xenon lamp is also produced in a high colour rendering version (Ra 85), but is designed to switch between two selectable colour temperatures (2600 K and 3000 K). This lamp is used where constant colour temperature is desired.

8. Electrodeless induction lamps

In 1994, GE Lighting introduced an electrodeless induction lamp, called the Genura lamp, designed to replace the incandescent reflector lamp (R80). Whereas the incandescent reflector lamp gives a light output of 1000 lumens at 100 watts (an efficacy of 10 lumens/watt) and has a life of 1000 hours, the Genura lamp gives a light output of 1100 lumens at 23 watts (an efficacy of 48 lumens/watt) and has a life of 10,000 hours. This lamp works on a principle of generating a high frequency current (2.6 MHz) to flow through an internal ferrite coil. This current produces a magnetic field which generates an azimuthal electric field around the coil. The free electrons are excited and collide with mercury atoms. This process generates UV radiation which excites phosphor on the inside of the tube which emits visible light.

A new electrodeless induction lamp called Endura, from OSRAM, will shortly be available that has an efficacy of 80 lumens/watt, a high colour rendering ability (Ra>80) and an extremely long life of 60,000 hours. It works on a similar principle to that of the Genura lamp, but operates at a lower frequency (250 kHz). It has a light output of 12,000 lumens and draws 150 watts. It is intended for locations where the replacement of lamps is costly. As there are no electrodes in these lamps, the life of the lamp is not affected by frequent switching but is based largely on the life of the electronic components.

Electronic high-frequency ballasts

The efficacy and output of discharge/fluorescent lamps (Fig. 4) varies depending on both the lamp and ballast installed. New electronic ballasts have been developed that have superior qualities over conventional wound-choke ballasts. In conventional ballasts there are losses due to the induction of the coil and iron core losses (such as development of eddy currents) which are dissipated as heat.

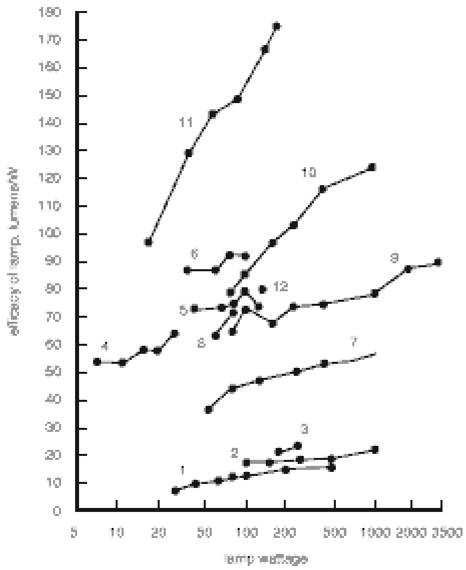

Fig.4
Efficacy of various lamps:
1 GLS incandescent lamp,
2 Tungsten halogen lamp (mains voltage),
3 Tungsten-ballasted mercury lamp,
4 Compact fluorescent lamp,
5 Standard fluorescent lamp,
6 High efficacy fluorescent lamp,
7 High pressure mercury lamp,
8 Sodium-xenon lamp,
9 Metal halide lamp,
10 High pressure sodium lamp,
11 Low pressure sodium lamp,
12 Induction lamp (Endura)
[Source: Osram Lighting Catalogue 1997]

Electronic ballasts are highly recommended for use with low-voltage tungsten-halogen lamps, high-efficacy argon-krypton filled fluorescent tubes (they are a standard requirement for the solely argon gas filled version), metal-halide and high-pressure sodium lamps. Electronic ballasts offer the following advantages:

- 20 to 30% energy reduction compared with conventional ballast
- 50% longer service life of lamps
- absence of flicker (ballast operates lamp at a frequency between 22-70 kHz)
- silent operation
- net power factor of 0.95 to 0.99
- low harmonic distortion
- overvoltage protection
- automatic switch-off of faulty or end-of-life lamps
- reduction in weight

- cool operation.

In addition, many electronic ballasts offer the ability of smooth and silent dimming.

Lighting Placement

One approach for reducing energy involves designing a space to be lit with both task and ambient lighting. The ambient lighting provides overall illumination and is kept at a modest level, while brighter task lighting is provided in the local work areas. This approach uses less energy than only overall illumination and at the same time provides lighting variation in the work place, which can be visually attractive.

Another standard method of lighting design is the PSALI (Permanent Supplementary Artificial Lighting in Interiors) developed as early as 1959 by Hopkinson and Longmore which provides a more balanced lighting system in an industrial space. Before then most installations were designed with luminaires evenly spaced across the ceiling. PSALI places more luminaires on the interior zone and less luminaires in the outer zone (near windows) (Fig. 5) or, as a retrofit, uses existing regularly-spaced luminaires with independent switching of each row (Fig. 6).

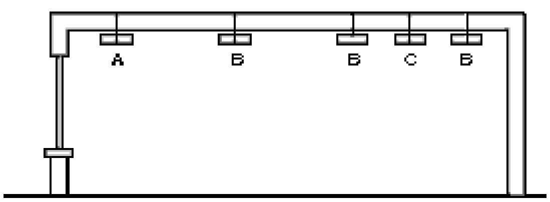

Fig.5
PSALI method for placing luminaires.
During the brightest portions of the day (when the daylight factor is high), only row C needs to be on (1 row on). When the daylight level drops (lower daylight factor), rows B can be turned on in place of row C (3 rows on). Only at night or very dark days (when the daylight factor is very low), would it be necessary to have on rows A and B (4 rows on)
(from Cayless and Marsden, 1983)

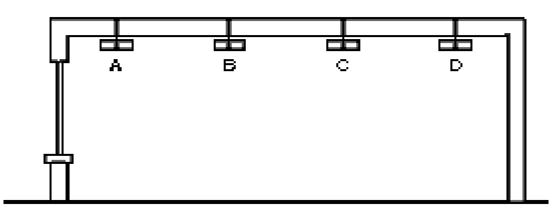

Fig.6
PSALI method used in a retrofit.
During the brightest portion of the day, row D can be on alone. When the daylight level drops (lower daylight factor), row C can be switched on, in addition to row D. When the daylight level drops further still, row B can

then be switched on, in addition to rows C & D. Only at night or on very dark days (when the daylight factor is very low), would it be necessary to have all 4 rows switched on
(From Cayless and Marsden, 1983)

Lighting Controls

Lighting controls now offer a range of methods that are both cost effective and energy efficient.

1. Localised manual switching - installation of local switches close to work stations to control the local lights. These systems provide more flexible control and thus encourage the switching off of lamps when not in use.

2. Time-based systems - installation of a timer to switch lights off during times when room is expected to be vacant. Timer circuits are wired with a manual override, so that the lights can be switched on again should they be required. An excellent example of using a timer is to switch lights off during the noon lunch break. Should there be adequate daylight in the room upon return, there is a high probability the lights would remain off for the balance of the afternoon.

3. Daylight-linked systems - use of photocells to monitor the amount of daylight in a room or at a work station. Photocell circuits can be used either to switch lights on and off (e.g. PSALI), or to dim lights up and down according to the local brightness. With the use of high-frequency ballasts, fluorescent lamps can be dimmed, flicker-free, to a very low level.

4. Occupancy-linked systems - use of occupancy detectors to switch lamps off when rooms are unoccupied. There are several different types of occupancy sensors available (infra-red, ultrasonic, acoustic or microwave), all of which detect either movement or noise. A time delay is included in these systems to suit the type of occupancy involved and avoid premature switching off at times of immobile and silent working.

5. Lighting Management Systems - use of Programmable Logic Controllers (PLCs). In recent years there has been much development in the area of sophisticated lighting management systems. Through PLC control, sensors are installed to monitor either daylight levels, occupancy status or both. The information is fed back to a PLC, which dims or switches a lamp or group of lamps according to a preset program. Through a program combining both daylight- and occupancy-linking the efficiency of the lighting system can be maximized.

In 1996 Philips Lighting introduced TRIOS-Multisense, a small PLC, with sensors that monitor both daylight level and occupancy status. The

PLC is designed to be installed into a luminare and will control a group of lights containing up to 60 electronic ballasts. The PLC has 5 preset programs which are activated by infra-red remote control.

In 1997 at the Hanover Light Fair, the firm WILA, from Germany, introduced a PLC light management system, for remote control operation. Their system "E Control Scenario" is daylight-linked but various occupancy sensors can be added. It can be programmed for various lighting scenarios. Different groups of lights can be switched or dimmed at various times, or as determined by the sensor information. This PLC can be programmed to provide permanent dimming to high intensity discharge lamps following start-up. This not only reduces energy consumption and costs but extends the life of the lamps. In addition, this PLC can be linked to a central computer, feeding data on lamp conditions throughout the system. Lighting management systems such as this are of particular value to building managers, as they can monitor the lighting status throughout an entire building.

Selected Case Studies

The following case studies (acknowledgments to BRESCU) show typical examples of savings occuring from improved lighting instalations in the UK, Eire and the Netherlands.

1. Romford Brewery Company Ltd, Romford, UK

procedure:

- replacing fluorescent-luminaire glow-switch starters with electronic starters
- replacing low-efficacy lamps
- installation of photoelectric daylight sensors and occupancy sensors
- implementing a planned maintenance schedule.

yielded:

- a 66% reduction in energy
- a simple payback period of 2.2 years

The four storey brewing company of this long-established company covers a site of approximately 10,000 m2. It is divided into 147 separate areas, most of which have no access to daylight. The upper stories of the building and stairways are however glazed.

A number of procedures were undertaken to improve the efficiency of the lighting installation. The number of luminaires was reduced from 1382 to 1045, and faulty luminaires were replaced. Remaining fluorescent luminaires fitted with glow-switch starters were fitted with electronic starters - an essential requirement for operation with occupancy-sensor control systems.

All 38 mm (T12) fluorescent tubes of 65 W and 20 W were replaced with 26 mm (T8) 58 W and 18 W equivalents. Most of the tungsten and high-pressure mercury lamps were replaced by compact fluorescents. The effect of all the lamp and luminaire changes reduced the installed power for lighting by 50%, to 81 kW.

A number of control systems were also installed. A daylight-linked control system uses photocells to detect the availabiltiy of daylight and adjusts the level of artificial daylight accordingly. Where appropriate, occupancy sensors have also been installed. Many occupancy sensors operate using infra-red, but where obstructions in the space prevent the use of infra-red sensors, microwave sensors were installed. The occupancy sensors have made a major contribution to the success of the refurbished installation.

A planned maintenance schedule was also implemented. Fluorescent and sodium lamps are replaced after 8,000 hours use. Hour-run meters were installed to monitor lamp use. The maintenance schedule has reduced maintenance costs by 40%.

Overall refurbishment has resulted in annual cost savings in excess of 48,964 ECU. The project cost was 104,923 ECU. Thus the simple payback period is approximately 2.2 years.

2. Dataproducts Ltd, Dublin, Ireland

procedure (a):

- installation of photoelectric daylight sensors with voltage control system

yielded:

- a 30% reduction in energy
- a simple payback of 1.5 years

procedure (b):

- installation of specular reflectors

yielded:

- an additional 50% reduction in energy
- a simple payback of 2 years

Dataproducts Ltd manufactures computer peripheral equipment. Its factory has a floor area in excess of 20,000 m2 and operates a multi-shift system. The original lighting installation consisted of 1567 twin lamp industrial reflector luminaires mounted on trunking and suspended approximately 4.5 m above floor level. Each luminaire was fitted with two 38 mm (T12) diameter each rated at 85 watts. The installation provided an illuminance of 300 lux during night-time operation and 500 lux during the day (an excess of 200 lux). The installation was divided across three lighting control zones and had a total power rating, inclucing control gear, of 300 kW.

A project was carried out to install a voltage control system for the lighting in the factory. The control system uses auto-transformers located in each of the three lighting control zones which are wired to a central control panel. The voltage control system has reduced energy consumption in two ways: firstly, following start-up the supply voltage is reduced by 12.5%, and secondly, using a photocell to monitor the daylight level in the factory the supply voltage is reduced by up to a further 5%. The illuminance was maintained at the required 300 lux, or greater.

A 30% reduction in energy consumed by the lighting installation has been measured, resulting in annual electrical cost saving of 22,000 ECU. The cost of the control system and its installation was 32,500 ECU, so the simple payback period was 1.5 years. The voltage control system was also observed to have the additional benefit of prolonging the service life of the lamps due to operation at reduced voltage.

The company has subsequently installed high-efficiency specular reflectors in each of the luminaires, allowing them to operate with just one lamp rated at 85 watts. This has reduced the installed lighting load by an additional 50%, while maintaining the required illuminance level of 300 lux in the factory. This additional project had an approximate simple payback period of 2 years.

The combined effect of the two projects has been to reduce the lighting energy consumption in the factory by 65%.

3. Van Doorne's Transmisse, Tilburg, Netherlands

procedure:

- installation of specular reflectors

yielded:

- an increase in light output
- a 50% reduction in energy
- a simple payback of 1.5 years

The Van Doorne's Transmissie factory is a production facility for drive belts. The floor of the factory measures 10,368 m2; the floor to ceiling height is 6.9 m and the floor to luminaire distance is 5.4 m.

Before refurbishing the factory was fitted with twin lamp luminaires each with two 58 W fluorescent lamps. The power used by each luminaire, including ballasts was 140 W. There were a total of 1701 luminaires. The total power rating for the lighting was 238 kW. The luminaires were in use for a total of 7038 hours per year. The total power consumption of the lighting installation was 1675 MWh per year.

Electricity charges were 0.043 ECU/kWh. The annual energy cost for the lighting was 72,025 ECU.

The most cost effective option was to fit specially designed specular reflectors to the existing luminaires. Before refitting the whole of the installation a small area of the factory was tested.

After the refit each luminaire ran with only one lamp, while maintaining or increasing light levels in the working area. Before refitting the average illuminance over the working area was 710 lux; after refitting it was 775 lux.

Cost analysis showed that by reducing the number of lamps by 50%, an annual energy cost saving of 36,012 ECU and maintenance saving of 7,202 ECU was achieved. The total investment for refitting the luminaires with specular reflectors was 86,580 ECU. The Dutch government awarded a grant for the installation of 21,645 ECU, thus reducing the net investment to 64,935 ECU. The simple payback for this installation was therefore 1.5 years. Without the government grant the simple payback would have been 2 years.

Conclusion

The preceding case studies show that reductions in lighting energy in excess of 65% can be realistically be obtained, while maintaining or improving the quality of light. The simple payback period for these lighting upgrades is typically between 1 and 3 years, following which the savings in energy costs appear as profit for the life of the installation.

Successful applications for retrofit obviously depend on the specific building conditions already in place, so that lights, ballasts, luminaires and control systems require careful amalysis. Lighting manufacturers offer design programs for this purpose. One of these is from Siemens, which is for buildings with a large number of fluorescent lamps, called the 3 step program. Step 1 is the installation of high-efficiency specular reflectors, for up to a 30% reduction in power costs depending on the installation beforehand. Step 2 is the installation of electronic ballasts for an additional 25% power reduction and Step 3 is the installation of daylight-linked control systems for an additional 25% reduction.

By considering all of the foregoing factors, including increased productivity due to a better quality of lighting in the building, reduced cost in air conditioning due to a reduction in heat from the use of new ballasts an reduced maintenance due to the extended life of the new lamps, retrofitting existing lighting installations can secure very worthwhile cost benefits.

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About the Author

Brian R. Cook is a licensed electrical contractor in Vancouver, Canada and is a member of the IBEW. He is particularly interested in lighting design, energy management and methods of sustainable energy production. Since March 1998, he has been working as Director of International Marketing and Sales for Heliocentris, Germany, a company developing and manufacturing fuel cells and solar hydrogen systems for the educational market. He can be contacted at:
Heliocentris GmbH, Rudower Chaussee 5, 12489 Berlin, Germany, Tel: +49 30 6392-6323, Fax: +49 30 6392-6329.

Return to Top