Energy Efficient LED Lighting

A Guide for Businesses

Preface

In the coming years, Ireland must use less energy, move to clean energy, and innovate to create new solutions to meet our energy needs. Businesses have a key role to play in transforming Ireland's energy system and energy efficiency is critical in this journey to a low carbon economy. Improving your organisation's energy performance makes sound business sense.

As Ireland's national energy authority, SEAI is investing in and delivering appropriate, effective and sustainable solutions to help Ireland's businesses transition to a clean energy future and realise their energy ambitions.

SEAI has developed this guide to help businesses deliver a successful energy efficient LED lighting project based on current best practice. Upgrading your lighting is an excellent opportunity for your business to make significant energy savings, often at relatively low cost and quick payback. Use this guide to help your business deliver a high quality, fit for purpose lighting system. It will save you money, improve your business' environmental performance and help you meet your corporate social responsibilities.

About SEAI

SEAI is Ireland's national energy authority investing in, and delivering, appropriate, effective and sustainable solutions to help Ireland's transition to a clean energy future. We work with Government, homeowners, businesses and communities to achieve this, through expertise, funding, educational programmes, policy advice, research and the development of new technologies. SEAI is funded by the Government of Ireland through the Department of Communications, Climate Action and Environment.

Table of Contents

Introduction

For many organisations, lighting is one of the most energy-intensive electrical services. It can be responsible for up to 40% of a building's electricity use (SEAI, 2018).

Many businesses still rely on inefficient technology to meet their lighting needs. However, advances in lighting technology, specifically LEDs and lighting controls, offer great opportunities to improve the quality, affordability and reliability of light.

LEDs provide good colour temperature, colour rendering, longer lifetime and increased efficiency. Lighting controls ensure that lights are only on when and where they are needed. The combination of these technologies are helping businesses to save money through reduced energy consumption and maintenance costs.

The best lighting for your business is one which is fit for purpose. Whether you are renovating an existing space or moving into a new building, a good lighting system will comply with the Irish Building Regulations and be designed with a building's end-use and occupancy requirements in mind.

While LED lighting retrofit projects generally deliver energy savings, the savings and the long-term success of the project will rely upon planning, specification and ongoing management of your project.

Achieving the best outcome from a lighting project will integrate the principles of energy efficient design and include the following key steps:

- Understanding LED lighting technology, processes and equipment;
- Understanding the current lighting system and user requirements;
- Identifying improvement opportunities and putting a business case together;
- Seeking advice, where appropriate, to assist in project implementation;
- Project implementation – including completing tender specifications, awarding contracts, installation, commissioning and handover;
- Measuring and verifying project energy savings to ensure they are achieved; and
- Managing the lighting system to ensure savings are maintained and continual improvements are made as opportunities arise.

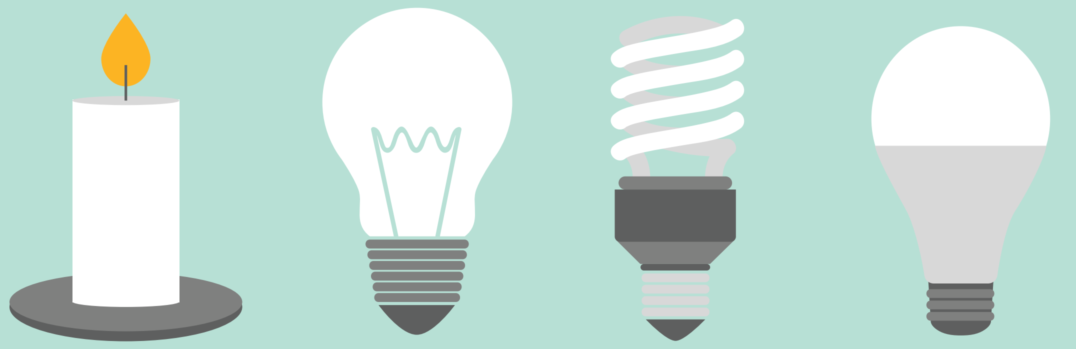
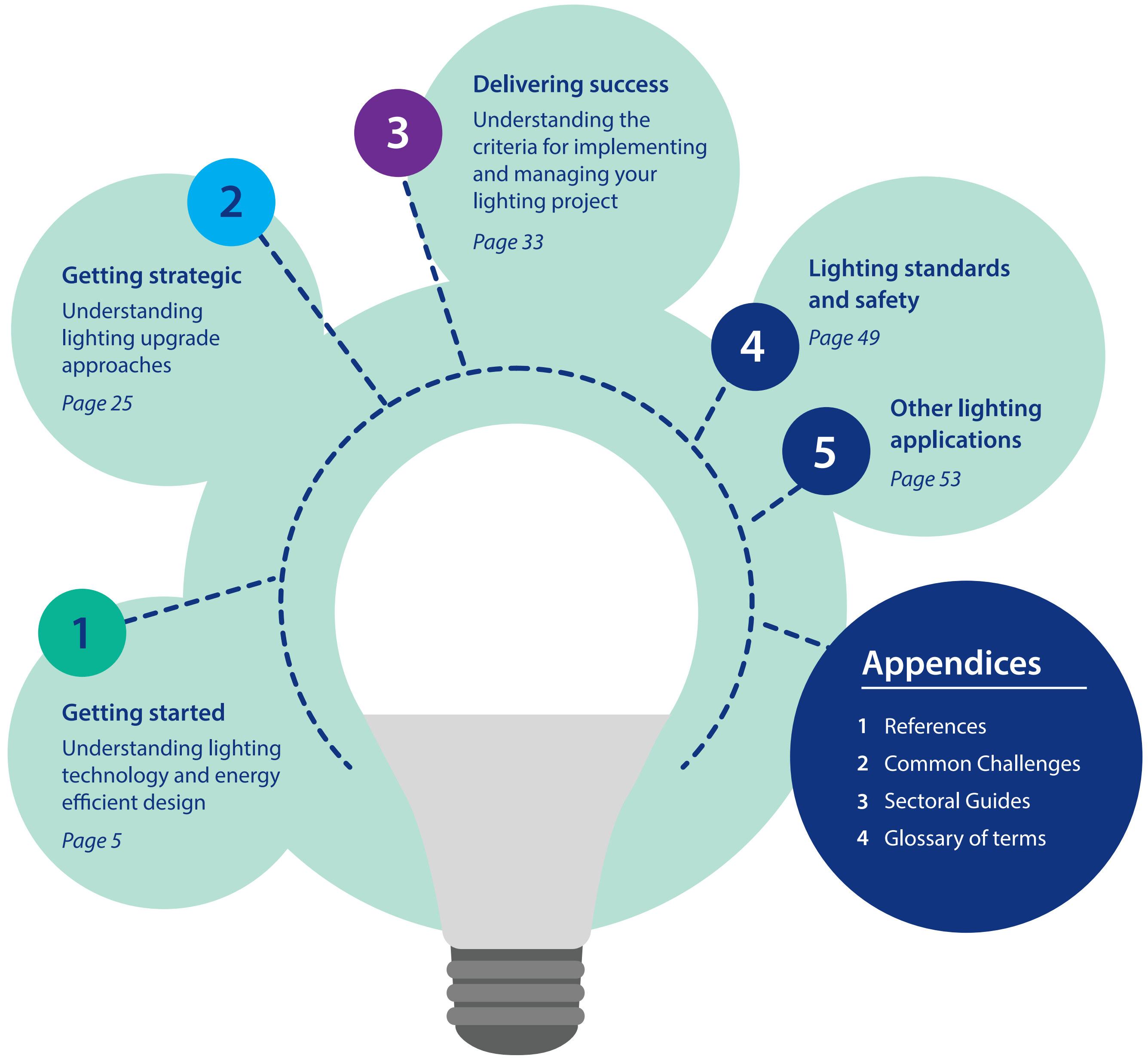


Figure 1: The evolution of lighting technology

How to use this guide

Whether you are at the start of your energy efficiency journey, or well advanced, this guide will help you to implement an energy efficient LED lighting project that will deliver sustained energy, operational and financial benefits to your business.

Navigate to the section which best suits your business needs. A glossary of terms is provided at the back of this document for your reference.



1

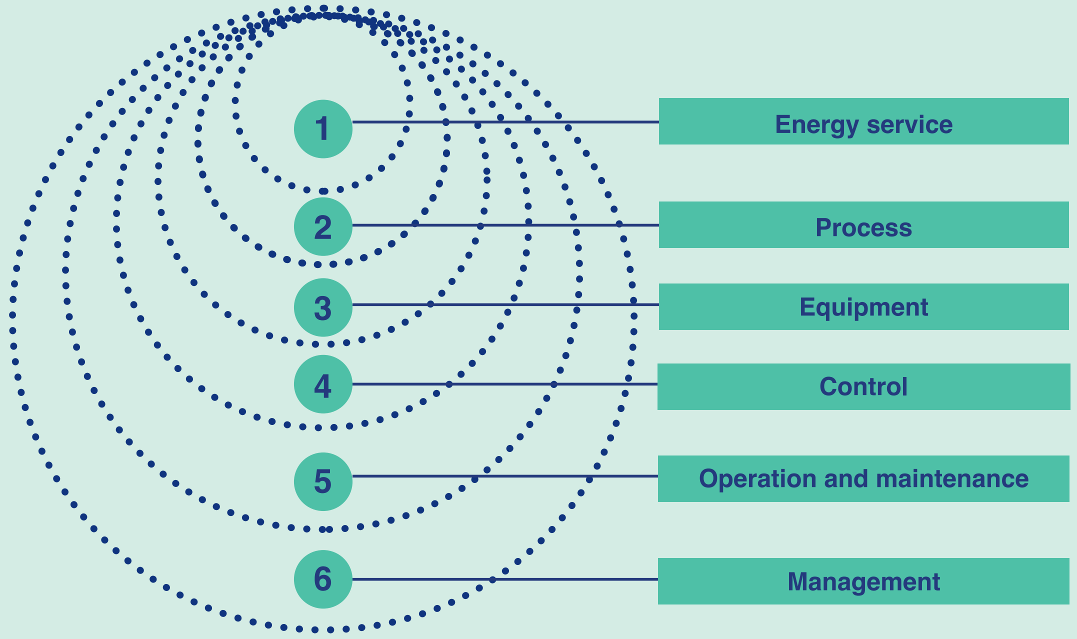
Getting started: Understanding energy efficient LED lighting

This section will help you to understand the best practice for energy efficient LED lighting and controls. The technology and design considerations within this section use principles from the IS399 Energy Efficient Design Management Standard to challenge and analyse the elements that affect the energy efficiency of a lighting system. This approach considers energy from the start of any new investment project, minimising energy consumption throughout its lifecycle and allowing your business to maximise cost savings through energy efficiency gains.

The Energy Venn diagram in Figure 2 on page 6, is a component of the Energy Efficient Design Management approach. It highlights that understanding the criteria affecting the energy efficiency of your lighting system requires a holistic approach to your project.

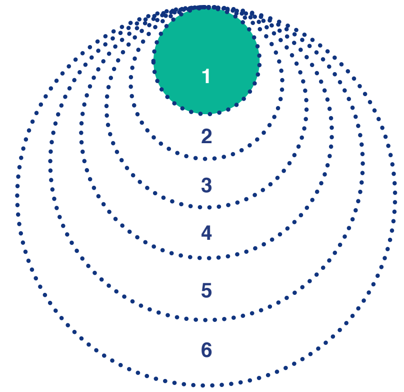
IS399 - Energy Efficient Design Management is an Irish standard developed by SEAI and the National Standards Authority of Ireland. Find out how IS399 can save money for your business at **www.seai.ie/standards**

Figure 2: Energy Venn diagram from IS399 of 2014 - Considerations for a typical lighting project



Layer	Description	Lighting example
1. Energy service	This is the need the project is aiming to fulfil. For a lighting project, the need is light, but it is critical to define what type of light, how much light and when and where it is needed.	Illumination and light distribution.
2. Process	This is where you examine the processes that can service the need: natural light or electric light.	Natural and artificial lighting.
3. Equipment	Consider what equipment can provide the light: windows, skylights, light pipes, reflective surfaces for natural light, different types of luminaires and reflective surfaces for electric light.	Luminaire specification – colour temperature, rendering and consistency, efficacy and technology lifetime.
4. Control	Examine how you can control the light, so you use the right amount and only use electric light when needed.	Lighting controls, sensors, systems and strategies.
5. Operation and maintenance	Assess how you will operate and maintain the lighting system.	Operation and maintenance plans. End of life considerations.
6. Management	Consider how you will manage and monitor the system over its lifetime to ensure no degradation in performance.	Energy management systems and stakeholder engagement. Continuous improvement. Measurement and verification.

1.1 Energy service: illumination and light distribution



Delivering a successful lighting project requires the designer and project manager to clearly understand why the lighting is required, how it will be used and where it is needed. Lighting levels and light direction are key to ensuring that any project will meet both the building's and user's needs.

1.1.1 Illumination

Lux is a measure of illumination, defined as the number of lumens per square metre hitting a surface. The greater the distance between the source and the surface the less intense the illumination. A lux meter measures lux levels.

For buildings, the lux levels vary depending on the activity within the space. For example, corridors and stairs do not need the same lux level as a classroom or a laboratory.

EN12464-1: Indoor Light Standards and the Chartered Institution of Building Services Engineers (CIBSE) Lighting Guides 2 – 9 provide a comprehensive list of the recommended lux levels for different areas. The list includes offices and retail space, as well as engineering tool shops, banking counter offices, boiler rooms and distribution stores, among others. When completing a lighting upgrade, lux levels should align with CIBSE recommended lux levels per building type and area standards to ensure safe working conditions.

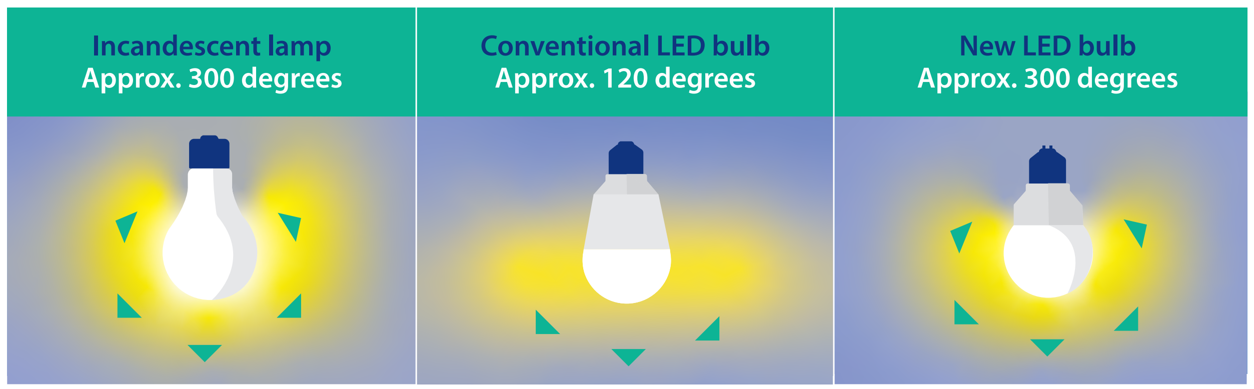
1.1.2 Light distribution

Light distribution refers to the evenness of illumination across the work area, floors and walls. This affects how those using the space perceive the brightness of light. When choosing a luminaire, you should consider the purpose of the lighting. For example, should it be narrowly focused and directional, or should it have a wide circular illumination? Matching the light distribution to the shape and space of the area to be lit not only avoids wasted energy, it also reduces light pollution.

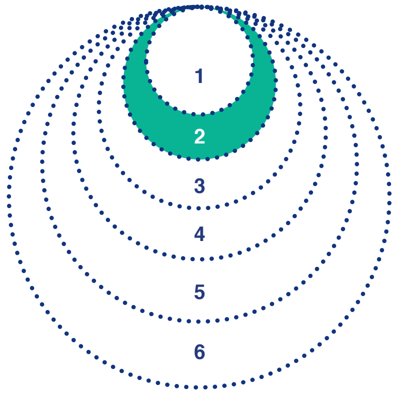
Uniform lighting is particularly important for work areas, for example, in an office space. If you light only the work desk area, the office may appear dark, even though lux levels on the working plane are adequate. Therefore, it is critical to also illuminate the walls for the area to appear bright and inviting to work in. CIBSE SLL Handbook (2018) and Lighting Guides outline in detail the lighting distribution requirements and best practice.

Early LED luminaires had a very directional distribution which made them unsuitable for replacement of general light service lamps. Advances in technology and omnidirectional LED lamps now offer a wider directional light output, allowing for a direct replacement for general service lamps.

Figure 3: Omnidirectional LEDs



1.2 Process: natural and artificial lighting

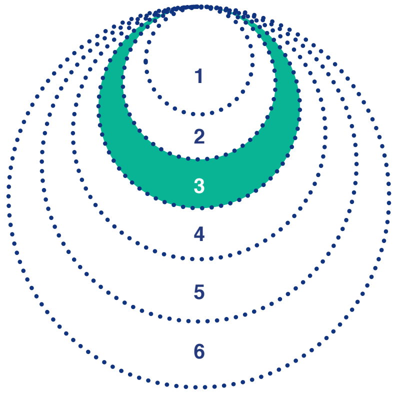


Lighting design can combine both natural and artificial light to optimise light distribution inside a building. Good lighting design will maximise the advantage from natural light. Good design can also provide excellent lighting effect and colour rendering, greater user comfort and reduced energy consumption and cost.

You can bring daylight into spaces through windows, roof lights and light tunnels. However, using natural light in a building can also bring challenges such as heat gain and glare from direct sunlight. Natural light levels also cause people to need to open and close window blinds and shades.

This needs to be considered during the design process for new buildings or can be minimised in retrofit projects by using appropriate shading devices. Light coloured walls and ceilings can assist in the distribution of daylight within your building.

1.3 Equipment: luminaire specification



LEDs are now the technology of choice for new and upgrade installations. They can match the colour temperature range and colour rendering standards of your current lighting while providing longer lifetime and improved efficacy.

There are many different types of LEDs and luminaires, at varying prices and quality. The quality of the lamp fitting can vary greatly in terms of light output, colour, efficacy, temperature and lifetime. Telling a contractor to provide a 32 W lamp is only giving part of the necessary information and can lead to varying quality lamp types and an even greater price range.

Therefore, when specifying LED lamps and luminaires, there are several key parameters which should be considered:

- Colour temperature;
- Colour rendering;
- Efficacy;
- Colour consistency (MacAdam steps); and
- Lifetime.

The following sections give more detail on these parameters and the key specifications of luminaires which will contribute to the lighting conditions immediately post-retrofit, and over the longer term.

Table 1: Relative performance of lighting technologies

	Colour temperature	Colour rendering	Efficacy	Lifetime
Standard incandescent	2,500 – 3,000 K	100 Ra	5 – 20lm/W	2,000 – 3,000 Hours
Tungsten halogen	3,200 K	100 Ra	15 – 24lm/W	2,000 Hours
Tubular fluorescent	2,700 – 6,500 K	>55 Ra	60 –105 lm/W	10,000 – 12,000 Hours
Compact fluorescent	2,700 – 4,000 K	>85 Ra	45 – 80 lm/W	6,000 – 15,000 Hours
High pressure sodium	2,000 – 2,700 K	25 – 85 Ra	25 – 85 lm/W	12,000 – 30,000 Hours
Metal halide	3,000 – 6,000 K	65 – 93 Ra	90 – 113 lm/W	6,000 – 20,000 Hours
LED	2,700 – 8,000 K	65 – 97 Ra	70 – 150+ lm/W	25,000 – 75,000 Hours

Adapted from: Bright ideas for efficient illumination (Carbon Trust, 2018) Crown Copyright.

1.3.1 Colour temperature

Different light sources offer different colour temperatures. While other specification criteria are generally similar for most building types, colour temperature needs will vary depending on the situation. Colour temperature refers to the colour of the light, measured in degrees Kelvin (K).

The colour temperature can affect the mood or feel of your space: a cool white light can feel clinical, whereas a warmer, more amber light can feel warmer and more relaxed. LEDs offer a wide range of different colour temperatures depending on the application.

Figure 4: Colour temperature range

1500 K | Warm white | Cool white | Daylight | 9000 K

Colour temperature	**2000-2500 K**	**2700-3000 K**	**3500-4000 K**	**4000-5000 K**	**5000 K+**
Effects on colours	- Strongly enhances blues - Flattens reds - Bluish tints to whites and greens	- Enhances blues - Flattens reds - Bluish tints to whites and greens	- Neutral Appearance - Enhances most colours equally - Does not favour yellow or blue	- Enhances red and orange - Blues appear darker - Yellow tint to whites and greens	- Strongly enhances red and orange - Blues appear almost black - Whites appear strongly orange
Typical applications	- Graphic arts studios - Seasonal Affective Disorders	- Offices - Hospitals - Manufacturing	- Retail stores - Supermarkets - Showrooms	- Residential lighting - Restaurants - Hotel lobbies	- Bread and meat displays - City beautification - Not for general lighting

The effect of **colour temperature** on the appearance of a room

Warm white | **Cool white** | **Daylight**

Additional considerations for colour temperature

- What is the ambient temperature for specified performance? Fittings in warm environments, above 30ºC, have a reduced life. LEDs work best in colder environments.
- What is the luminaire mechanical integrity and IP (international protection) rating? Where there is excess moisture or dust in the air this value should be IP65 or above.
- Do you have any sensitive environments such as explosive atmospheres or danger zones which need to be considered?

1.3.2. Colour rendering index

The colour rendering of a lamp refers to the accuracy in which you can see colour. It is specified using the colour rendering index (CRI). The index is measured from 0 – 100, where 100 indicates that colours under the light source appear the same as they would under natural sunlight.

The importance of colour rendering depends on the user's need to see an object's colour as it would look under daylight. Good colour rendering is particularly important in retail stores where customers want a true view of the product they may want to buy. An example of poor colour rendering is sodium vapour street lighting, which can show roads and footpaths with a yellow or orange glow and make it difficult to distinguish between colours.

Figure 5: Colour rendering index

Reasonable CRI **60**	Good CRI **80**	Excellent CRI **90**
<80	**80-90**	**90+**
Objects may not appear as their true colour.	Considered sufficient for most indoor applications as per EN12464-1 Indoor Lighting Standards.	This value would be required in clinical areas such as hospitals and healthcare buildings.

1.3.3 Colour consistency – MacAdam steps

As in all manufacturing, no two products are exactly the same. LEDs are no exception. The colour consistency of LEDs (sometimes referred to as the chromaticity tolerance) is related to their production, with variations in colour consistency measured in 'MacAdam steps'.

MacAdam steps are used to determine colour precision of LEDs. LEDs produced within one MacAdam step appear to be exactly the same colour to the naked eye.

Specifying fewer MacAdam steps equates to greater colour consistency and specifying more MacAdam steps equates to lower colour consistency.

If consistent colour is important to your project, for example in a retail store, choose LEDs with a small number of MacAdams steps. In general, high quality products are typically within three steps on the MacAdam ellipse, which is often a good balance of quality and cost.

1.3.4 Luminous efficacy

The efficacy of a lamp is the ratio between its output in lumens and its power consumption in watts.

$$\text{Efficacy} = \frac{\text{Total lumen output}}{\text{Circuit power drawn}} \quad (\text{lm/cW})$$

Where:

- Total lumen output (lumens) = total light output from the lamp.
- Circuit power drawn (also known as circuit watts) = electrical power drawn by the whole luminaire, including losses in the LED driver.

LEDs have the highest efficacy and are therefore generally the most energy efficient lamps that produce the best light quality in terms of lumens and lux. However, lamp efficacy and luminaire efficacy are often different.

Luminaire efficacy takes account of the whole fitting efficacy and this is the correct efficacy to consider when setting the requirements for your lighting project.

It is extremely important that you evaluate the efficacy of the entire fitting (lm/cW), rather than just the LEDs or lamps within the luminaire. Specifications for luminaires are much more consistent than they were several years ago, but it is always worth checking to see if the efficacy listed is for the full luminaire so a direct and fair comparison can be made.

1.3.5 Lifetime and light output

The lifetime of a lamp is the number of hours the light will burn before failing. Lamps with a longer lifetime need replacing less often, and therefore reduce both capital and maintenance costs.

The useful life of standard lighting technologies is defined as the time until filament or cathode failure. For most lamps, the period prior to failure exhibits acceptable levels of light output. However, as LEDs do not have a filament to burn, the light source output falls by a given percentage after a specified number of hours as illustrated in Figure 8.

LED lifetime and output are therefore considered in terms of their attributed L and B numbers, where:

- L represents the lifetime of a lamp relative to its percentage output, for example an LED rated L80 with 40,000 hours reveals that the lamp can last for 40,000 hours before the brightness or lumen output will be reduced to 80% of the original output.
- B represents the percentage of LED modules that will be below the stated 'L' number, after a certain number of hours.

In practice, the life expectancy of a fitting also depends on environmental factors such as temperature and voltage level variation. Warmer environments decrease the lifetime of luminaires.

Figure 6: MacAdam ellipses

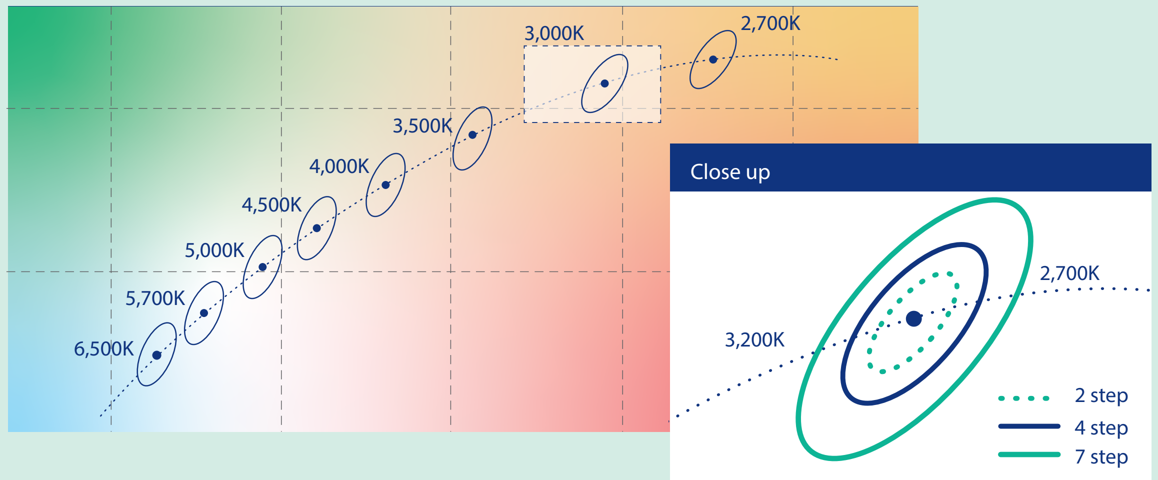
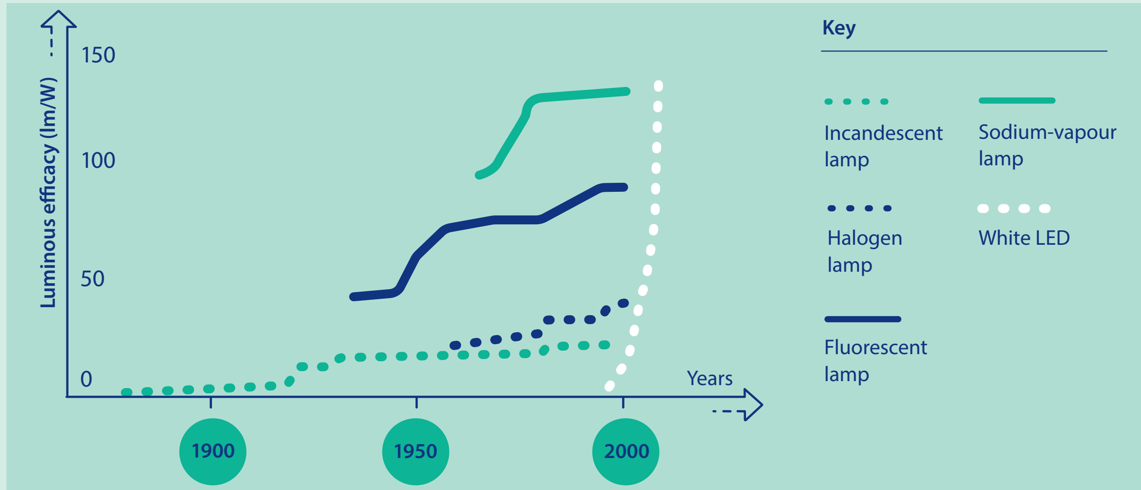
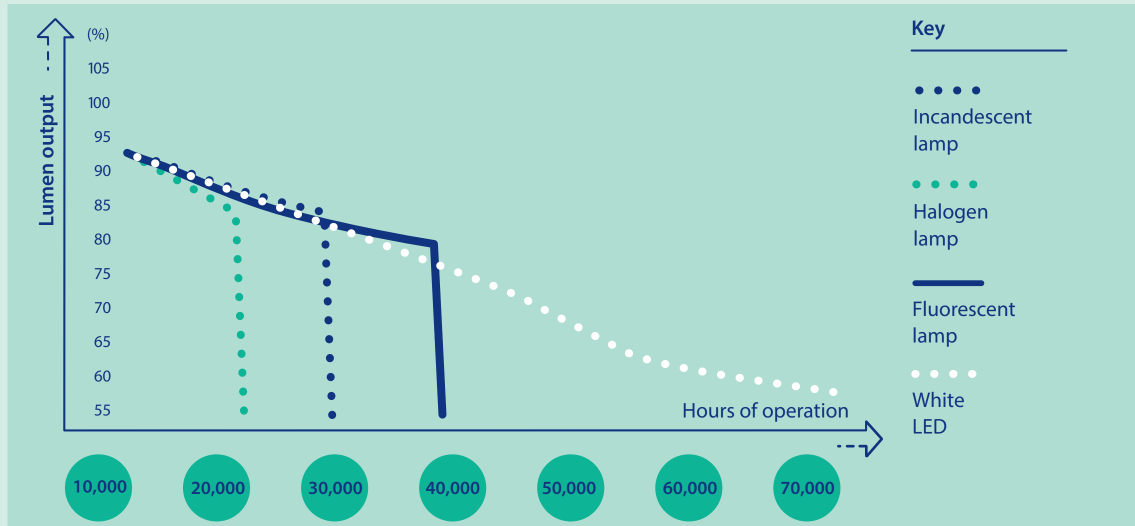


Figure 7: Lamp efficacy



Adapted from: A review of LED technology trends and relevant thermal management strategies (Pryde, et al., 2014)

Figure 8: Hours of operation



Top tips

1. Look for luminous efficacy of 100 lm/W or more for high efficiency interior LEDs.
2. The Office of Public Works specify L70B50, and 50,000 hours for their lighting. This high standard can be considered as a best practice benchmark for selecting your lighting performance criteria.

Constant light output

The light level of LEDs reduces over time as the diode ages. Many luminaires contain an integrated driver which compensates for the light depreciation over time by gradually increasing the power output. This feature, called constant light output (CLO), allows a lamp to maintain a constant lighting level over its lifetime.

Constant light output may be an important feature where dimming control is not installed. It allows light levels to be maintained where controls are unavailable to compensate for luminaire degradation.

Example for an L80 rated LED module with a lifetime of 40,000 hours:

- The driver is programmed so that the initial power output is at 80%;
- Over time, as the LED ages, the driver gradually increases the power output to 100% to ensure that the required lighting level is being achieved;
- A constant light output of 80% is provided over the lifetime of the lamp.

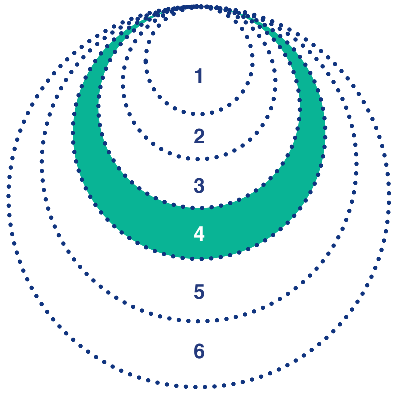
Best practice guidance for your lighting specification

The Office of Public Works has developed a general office lighting performance specification detailing the minimum requirements for the retrofit lighting in their buildings. In 2017, this specification was established as the higher end of what was available in the market, particularly for efficacy. However, improving specifications make this standard more achievable year on year.

Table 2: Office of Public Works office lighting specifications

Factor	Minimum requirement
Light source	LED
Colour rendering index	>80
Colour temperature	4000 K
Minimum efficacy	130 lm/W
Lifetime	Median useful life: L70B50, minimum driver lifetime: 50,000 hrs
MacAdam step	3
Control compatibility	DALI
Warranty	5 years

1.4 Lighting controls



Energy efficient lighting can reduce the energy used in illuminating your building. However, we have all driven by a building at night, or walked into an unoccupied part of the building, and wondered why all the lights were on. Introduce better lighting controls for a cost-effective way to ensure lights are not left on unnecessarily and to maximise natural light.

Lighting control can be provided by:

- Manual control using localised switches and dimmers;
- Localised automatic control using timers, occupancy and photoelectric daylight sensors; and
- Central control systems.

The flowchart in Figure 9 provides a method for selecting an appropriate control strategy.

The positioning of light switches and sensors, and the control strategies you use can play an important role in reducing your lighting bills. By using one or more lighting control strategies, you can minimise energy consumption.

Lighting control has a major human aspect and it is important that all building occupants understand how the controls work to maximise benefit and mitigate misuse. Work in collaboration with the occupants to create your control philosophy and to ensure it meets their needs.

Figure 9: Selecting lighting controls

Is daylight available?

Yes

Multiple occupants

Variable occupation
- ● Time switching (strongly recommend)
- ● Localised switches (could be expected)
- ○ Photoelectric daylight linked
- ○ Occupancy linked

Intermittent scheduled occupation
- ● Time switching (strongly recommend)
- ○ Localised switches
- ○ Photoelectric daylight linked
- ○ Occupancy linked

Full Occupation
- ● Time switching (strongly recommend)
- ● Photoelectric daylight linked (strongly recommend)
- ○ Localised switches

One or more occupants

Variable occupation
- ● Localised switches (strongly recommend)
- ● Occupancy linked (could be expected)
- ○ Time switching
- ○ Photoelectric daylight linked

Full occupation
- ● Localised switches (strongly recommend)
- ● Photoelectric daylight linked (could be expected)
- ○ Time switching

Very low occupation

Intermittent occupation
- ● Occupancy linked (strongly recommend)
- ● Localised switches (could be expected)
- ○ Time switching
- ○ Photoelectric daylight linked

No

All occupancy types

Intermittent occupation
- ● Time switching and localised switches (strongly recommend)
- ● Occupancy linked (strongly recommend)

Key
- ● (green) Strongly recommend to produce savings
- ● (dark blue) Could be expected to provide savings but rate of return on investment would not be as high
- ○ Needs consideration – might depend on a detailed examination of the installation

Adapted from: Indoor lighting in the public and private sector service sectors (Premium Light Pro, 2017)

Table 3: OPW office lighting control strategy

Cellular offices	Open plan offices
DALI PIR controller	Networked KNX/DALI PIR controller
Retractive switch - Push on - Push off - Hold for dimming	**Retractive switch bank** - Push on for each area - Push off for each area - Hold for dimming - Master off switch for total area
Setpoint to recommended or user defined lux	Setpoint to recommended or user defined lux
Manual switch on (to setpoint) when entering room	Presence detection to on (to setpoint) in each area
Absence detection to off – timed	Absence detection to off in each area – timed
Daylight linking available but not activated	Daylight linking available but not activated

1.4.1 Manual switching

Manual switching involves switching lights on and off to activate a luminaire or set of luminaires. In open plan offices there are wide variations in user preference for lighting. Some occupants prefer lighting always on and others only when it is necessary.

In areas with high occupancy, you can achieve greater energy savings with localised switching compared to a central control switch of the entire space.

With automated controls, you can override them with manual switching such as a master switch to turn off all lights in an area at the end of a working day. It is not unusual for new buildings to have no manual switching at all now, with all switching happening automatically.

Top tip

Looking for a lighting control system for your office? Check out the Office of Public Works general office lighting control strategy, which details the minimum requirements for control within cellular and open plan offices.

1.4.2 Daylight controls

Daylighting is the term used when natural light is used to illuminate a building. Daylight controls establish the level of light in a room and adjust the amount of artificial light accordingly. There are two options for daylight control:

1. On-off switching which turns luminaires on or off when a certain level of daylight is reached. You should build a time delay into this system to avoid regular switching during times of variable cloud cover.
2. Dimming matches the daylight level with the electric lighting output from the luminaires. For example, during times with low level of natural daylight, luminaires can dim up or down in response to background lux levels. Dimming provides greater savings than on-off switching.

You can place sensors centrally (or in several locations) in a room to control a selection of luminaires. Alternatively, you can place them individually beside each luminaire, or even integrate them into each luminaire (see Figure 12). Individual sensors best suit rooms that have a higher distinction between naturally lit and shaded areas. Centrally placed sensors are more suited to areas where lighting is more consistent across the space.

Figure 10: Manual controls switch bank with list of areas being controlled

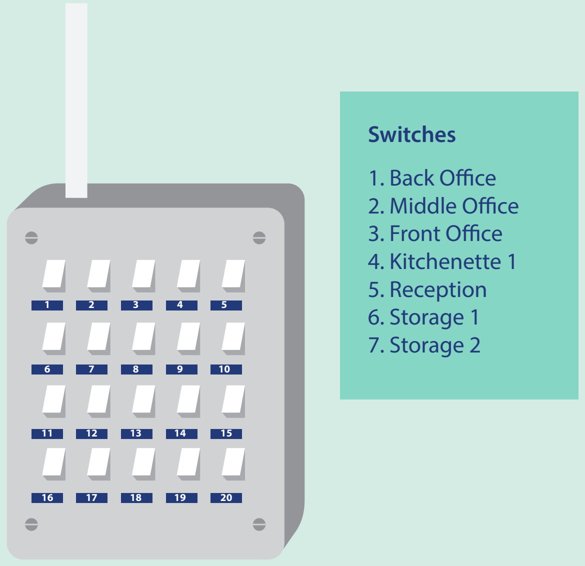
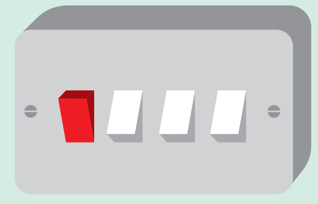


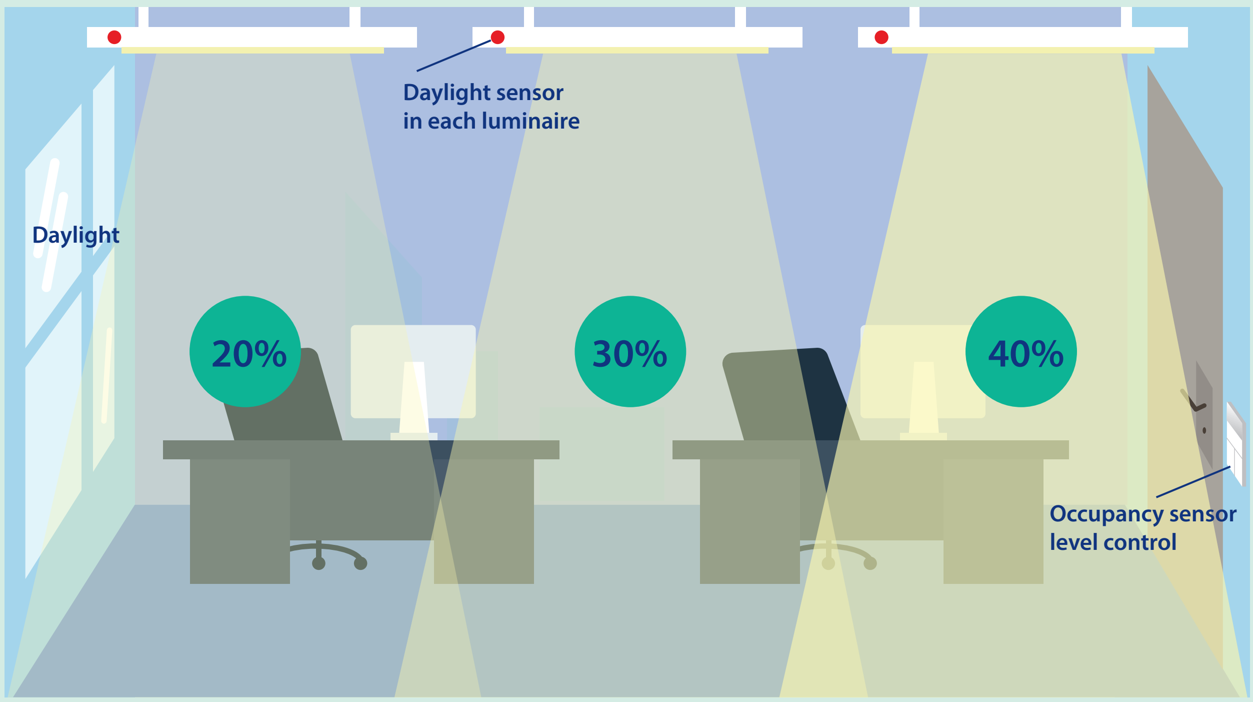
Figure 11: Open plan switch bank with area switches and master off switch



Top tip

Provide a list, legend or key alongside master controls switch banks to easily identify which switch operates which light.

Figure 12: Daylighting controls – individual luminaire sensors



1.4.3 Motion sensors

Motion sensors (also referred to as occupancy sensors) turn lighting on or off in response to motion, or lack of motion. You can set them for absence detection, presence detection, or both, and they can be fitted with timers.

- With presence detection, sensors switch on lamps automatically when you enter the room. They switch off lamps automatically when no movement is detected after a period of time.
- With absence detection, you switch on lamps when entering the room. When leaving the room, the sensor switches off the lamps. You can also switch them off manually.

Motion sensors are most suited to areas with intermittent uses, for example toilets, staircases, corridors, hallways, storage rooms and areas with unpredictable use such as meeting rooms, cell offices, classrooms, laboratories. There are two main types of motion sensors:

1. Passive infrared (PIR) sensors which detect heat from a moving object and require a direct line of sight (very common).
2. Microwave sensors which respond to a reflected microwave from a moving object. These are more sensitive and do not require a direct line of sight. Sometimes they are used in stairwells.

1.4.4 Automated time controls

Automated time controls involve turning luminaires on-off in an entire building or in a particular space at times you specify or for a particular duration of time. They are suitable for:

- Buildings that have set-times of operation such as offices, retail stores;
- External, perimeter lighting only needed within certain hours; and
- Rooms with natural short occupancy periods such as toilets, closets, plant rooms and server rooms

Automated controls should have a manual override switch that can operate the lights outside of the normal times and in emergencies.

Set times can be wasteful during periods of ample daylight. To maximise savings and prevent waste, use photocell controls to adjust lighting output in response to natural light.

1.4.5 DALI

DALI (Digital Addressable Lighting Interface) is an International Standard lighting control system (IEC 62386) used to integrate and control lighting systems. Simply put, DALI allows two-way digital communications between luminaires and lighting control elements providing enhanced and programmable lighting control. DALI is a commonly used standard in industry and, due to its open access nature, allows interoperability across various manufacturers.

With DALI, lighting components including luminaires (individual or grouped in circuits), sensors and switches can be linked back to a localised (per room/area), or centralised DALI compatible control system, by a network (see per Figure 13). As the space or occupant needs change, the system can respond by reassigning control systems to different luminaires accordingly. This system enables greater control and greater energy savings.

DALI controls require capital investment in the luminaires and associated controls, however they provide a future-proofed control system. DALI design needs to be aligned with how occupants, visitors and others use the building. Depending on the existing lighting configuration, a DALI system may be more appropriate for new-builds: it can be difficult to retrofit into existing buildings, and there is a potential increase in costs.

If you install DALI controls, train the facilities manager or another member of staff on how to use them. A maintenance contract should be established to annually review the system and setpoints to ensure the system is operating appropriately for the building's and occupants' needs.

Wexford County Council's DALI system drives energy savings

Wexford County Council County Hall offices installed a DALI system to improve its energy efficiency. The building is divided into different lighting zones. The zoning of the building for offices, corridor spaces, canteen, toilets, open areas and stairwells allows for the setting of different levels of lighting and the use of different types of controls. The DALI system helps with correct monitoring to ensure the most efficient settings have been applied, and that they are working correctly.

1.4.6 Ethernet controlled lighting

An emerging approach to new installations of LED lighting systems is power over ethernet (PoE). This approach allows both power and communication to the luminaires via a single ethernet cable such as a Cat6.

With modern, lower power luminaires, this can remove the requirement for AC electrical cabling for power supply. A communication cable to each luminaire facilitates sophisticated lighting controls.

In a retrofit situation, the existing AC electrical cabling can be retained to the luminaire, but control can be achieved through a separate ethernet connection to each luminaire.
This may allow more complex lighting controls that the existing electrical wiring would typically not allow.

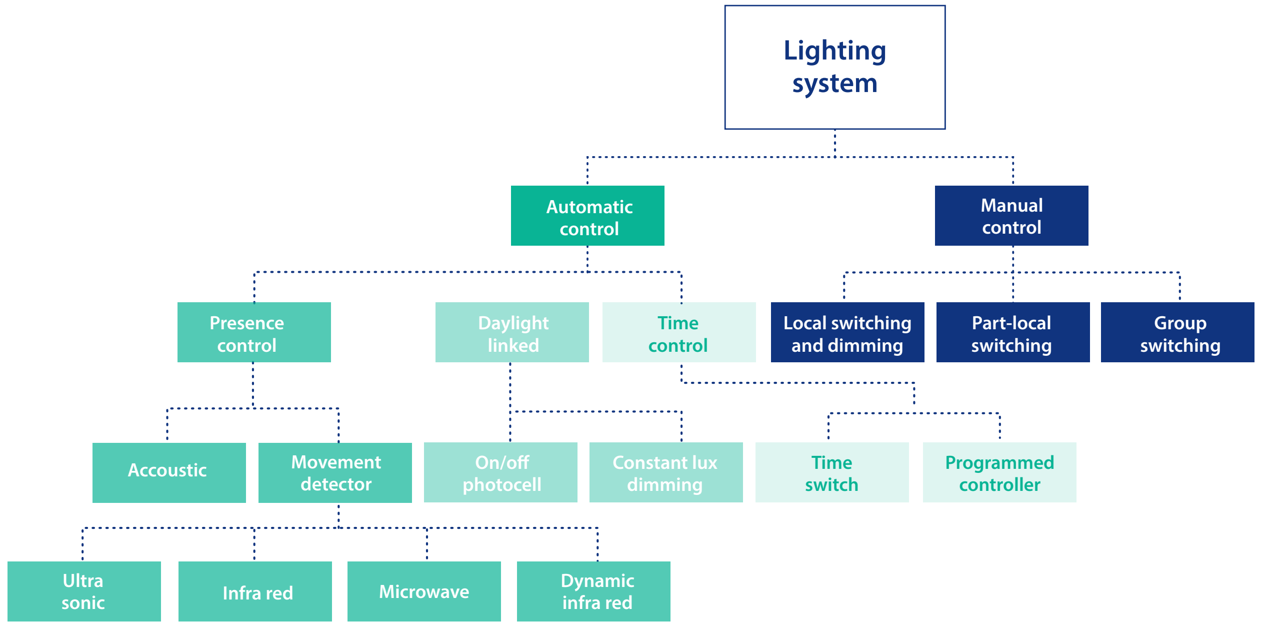
Supporting this technology, Internet of Things (IoT) sensors and switches are now available. These allow the installation of wireless daylight control, absence detection, and switching/dimming stations. This approach can prevent the requirement for additional or new wiring in the installation, enabling easy reconfiguration of workspaces over time.

Internet of Things technologies can be integrated with the building energy management system and can be used to collect additional data such as occupancy.

1.4.7 Summary of common control strategies

A complete list of control options is shown in Figure 13 and some of the most common control choices are outlined below in more detail.

Figure 13: Control strategy options



Common control choices for business spaces

Open plan offices

As open-plan offices are generally larger than cellular offices and have multiple occupants, consider a number of automatic controls such as:

- Time switch – for hours of operation;
- Absence/presence detection controls;
- Banked controls for different areas within office; and
- Daylight linked controls.

Cellular office

Consider automatic and manual controls, as well as:

- Time switch – for hours of operation;
- Absence/presence detection controls; and
- Daylight linked controls.

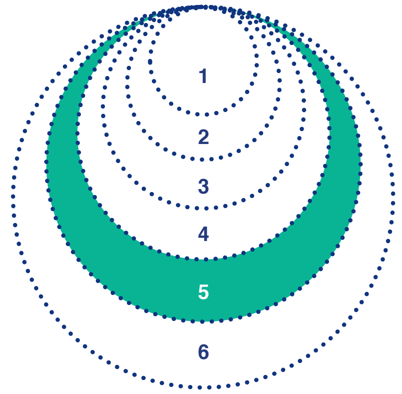
Warehouse

Consider automatic controls, including:

- Time switch – for hours of operation;
- Absence/presence detection controls for working areas;
- Master switch for control of main thoroughfares for safe access; and
- Daylight linked controls.

Further guidance on lighting retrofit for offices, retail, hotels and warehouses is available in Appendix B.

1.5 Operation and maintenance



Lighting operation and maintenance should not be a reactive task. Before you make design decisions it is important to plan and consider the end user, access, cleaning and maintenance. If there is an undesirable maintenance task involved in your existing lighting (such as operating at height or difficult access) you should consider designing this out for a retrofit.

At a minimum, operation and maintenance plans for lighting should consider:

- A routine replacement programme. Replacing individual lamps as they fail requires frequent maintenance and can increase maintenance costs.
- Group re-lamping (replacing all lamps at planned intervals, based on their expected lifetime) to minimise maintenance. This will ensure the installation gives a uniform appearance. Schedule re-lamping with luminaire cleaning.
- Dusting and cleaning. Installations accumulate dirt over time: this reduces light output. Dusting lamps and cleaning the surfaces enhances lighting performance by allowing the fixture to perform optimally. At design stage, ensure luminaires are accessible from below the ceiling for ease of maintenance.
- Controls and DALI maintenance. Train someone within the building to use the system. It may be a requirement to set up a service contract with the installer to ensure that the system is updated and reviewed following installation.

Did you know?

Due to their longer operating hours compared to traditional lamps, you can reduce maintenance costs significantly with LED lamp upgrades.

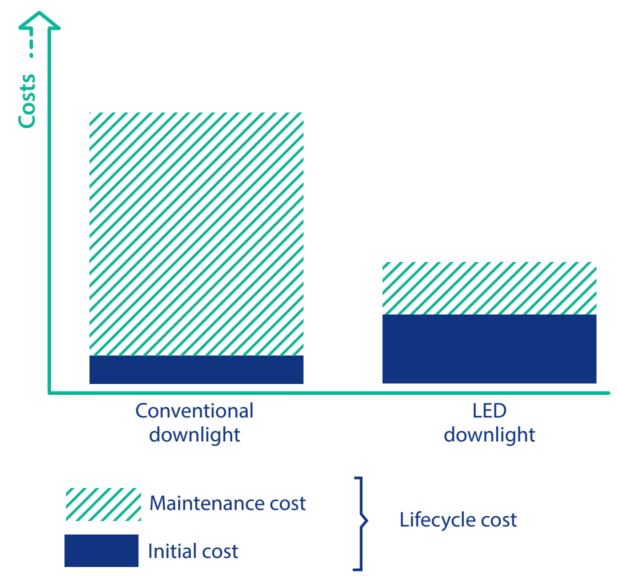
1.5.1 End of life and disposal

Never put lamps or luminaires in either your waste disposal or recycling bins. Under the European Community Directive 2012/19/EU on Waste Electrical and Electronic Equipment (WEEE), retailers are required by law to take back old lamps free of charge. They must do this on a one-for-one basis when a customer buys new lamps.

Also, each local authority must accept old lamps free of charge at civic amenity facilities from members of the public. Local authorities cannot charge gate fees for the old lamps.

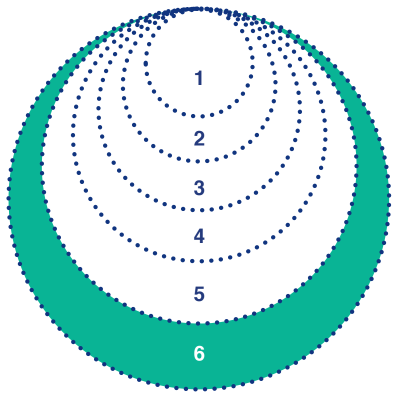
In most cases, installers will take the old lamps away and dispose of them. Ensure this is a clause in the installation contract with the installer.

Figure 14: Maintenance costs



1.6 Management

All lighting projects require ongoing management to ensure that they continue to deliver the projected energy savings over their lifetime. An energy management system is a formal process for overseeing energy projects and for continually improving energy performance. Suitable for all organisations, whatever the size or sector, energy management systems are particularly beneficial if you operate energy intensive processes.



Adopting an energy management system will deliver greater energy savings than an ad hoc approach. Moreover, continual improvement ensures you remain alert for new opportunities as they arise and exploit all areas where energy savings can be achieved.

There are a variety of energy management approaches to choose from, depending on your organisation's size and energy profile. They include SEAI's Energy MAP training and ISO 50001:

- SEAI Energy MAP (Energy Management Action Plan) is SEAI's primary energy management programme. It has been developed for organisations of every scale, from small to very large energy users. It can assist in the overall energy management and reduction of energy consumption.
- ISO 50001: 2018 – Energy Management is an international standard for best practice energy management. The methodology is based on the plan, do, check, act process to formally structure your organisation's approach to energy management.

Whether your organisation is implementing or pursuing a formal energy management system or certification or not, the following principles will guide you on saving energy and driving continuous improvement for your lighting projects.

Top tip

If you have identified lighting as a significant energy user in your organisation, you should regularly measure and verify its performance to ensure you are getting the anticipated energy savings. Section 3.6 provides further guidance on measurement and verification for lighting projects.

Principles of energy management

- Develop and implement an energy policy and gain commitment from top management to support your organisation in good energy management practices.
- Identify how much energy you are currently consuming and where it is being consumed.
- Identify the opportunities for energy savings. Prioritise them, select the most suitable opportunities for implementation and undertake them.
- Measure your energy consumption regularly to see if your projects are delivering the projected improvements, and to identify where energy consumption is greater than targeted.
- Improve your energy performance and energy management system by continually identifying new opportunities and implementing them, and continually measuring performance and reacting to the results.

For further guidance on energy management systems, support and training, visit SEAI's website: **www.seai.ie/standards**

2

Getting strategic: Lighting upgrade options

Depending on your business requirements, your lighting upgrade project will generally take one of three main approaches: lighting redesign, luminaire replacement, or lamp replacement.

Unlike lamp or luminaire replacement, lighting redesign allows you to fully evaluate where and how you use lighting and design a system that best fits your needs.

While the capital investment can be higher than luminaire or lamp replacement, lighting redesign is likely to offer your business higher energy savings year on year.

Table 4: Lighting upgrade options

Retrofit Approach			
Description	**Lamp replacement** Lamps, bulbs and tubes are replaced with more efficient versions in existing luminaires.	**Luminaire replacement** Luminaires, or fittings, refer to the whole fitting, including the lamp and the control gear housed inside it. Full luminaires are replaced on a like for like basis with more efficient versions.	**Lighting redesign** A new lighting design is developed according to current best practice.
Cost	**Low**	**Medium**	**Medium to High**
Typical energy savings*	**50% or more**	**60-75% or more**	**70% or more**
Considerations	Ballast and controls need to be considered. Does not tackle existing design deciencies.	Does not tackle existing design deciencies. Need to assess if lighting levels will remain acceptable.	Cost very dependent on ancillary costs, e.g. ceiling repairs.

2.1 Lighting redesign

Redesigning a lighting system aims to improve the lighting configuration within a building and is considered as a blank canvas approach to lighting. Redesigning not only replaces lamps with more efficient ones but offers the possibility of reducing the number of fittings needed while enhancing the overall lighting levels. In addition to tackling energy efficiency, lighting redesign can address the suitability of light levels, glare, uniformity and lighting specifications.

In general, lighting redesign involves the:

- Assessment and calculation of lighting requirements;
- Considered selection of the right luminaires and lighting controls to achieve the required levels during the time that they are needed; and
- Relocating, removing or adding luminaires to ensure that light is provided for, and positioned towards, the required areas.

A lighting redesign approach is the optimal solution if your building's lighting system was not originally designed for its current use, or the current luminaire locations are not fit-for-purpose.

The drawback to redesign is that it requires more up-front design costs and may require works to redecorate. Therefore, the complexity, cost and energy savings for the project need to be assessed before taking on a lighting redesign. In all cases, lighting design should be completed by a suitably qualified and experienced professional lighting designer.

Did you know?

Human centric lighting is the latest innovation in energy efficient and intelligent lighting design. This approach places human health, productivity and wellbeing at the centre of its design philosophy. It offers smart, sustainable and controllable lighting solutions that are responsive to human experience.

Loughboy Library carry out a lighting redesign

Loughboy library in Kilkenny carried out a review of its operations in 2017 and decided to upgrade the building. The original lighting system comprised of forty twin T8 fluorescents. The new design reduced this to twenty-five 35 W LED 600 x 600 mm panels. Energy savings were 8,850 kWh or an 83% reduction on lighting load.

The upgrade included the installation of a false ceiling to enable the redesign of the lighting and emergency lighting. The library repositioned luminaires from over the book racks to over the aisles, ensuring that lighting is now positioned exactly where it is needed. The redesign project also resulted in a reduction in the overall number of luminaires, offering cost and energy benefits over the course of the project's lifetime.

Description	Before	After
Lamp type	T8 twin fluorescent tubes	LED
Wattage	58 W	35 W
Lumen output per fitting		4194 lm
Energy consumption	10,700 kWh	1,850 kWh
Project cost	€10,000	
Simple payback	7 years	

SEAI can help you put energy efficient design into practice

SEAI EXEED (Excellence in Energy Efficient Design) provides a structured approach to energy efficient design management to maximise energy and carbon performance.

It ensures energy is considered at the design stage, where 90% of energy costs and carbon emissions are locked-in. This enables the biggest energy savings throughout the life of the building or process. The SEAI EXEED approach helps businesses become more efficient, competitive and resilient. It also provides a framework for ongoing energy management, once the building or process is in use.

As part of the programme, SEAI also provides a grant scheme up to the value of €500,000 per year per project to help businesses embed energy efficiency measures in the design of their projects.

For further information on how EXEED can help your business please visit:

www.seai.ie/exeed

Dublin Airport Authority achieved savings of 80% on its carpark lighting costs by implementing SEAI EXEED

Dublin Airport Authority was one of the first organisations to progress its project through all three stages of the SEAI EXEED certification system for their carpark lighting upgrade project.

Following the lighting and control upgrades, their electrical savings are almost 964,500 kWh – the equivalent of powering about 1,200 floodlights per annum.

The project was ambitious from the beginning. Dublin Airport Authority wanted to challenge the norm and develop infrastructure that is of the highest environmental and performance standard.

This means that the airport:

- has used a design-led approach to energy savings;
- has verified the energy savings being achieved; and
- is managing the operation for continued savings and best practice in energy efficiency.

They researched other similar projects and trialled various lighting levels to find out what worked best for their needs. Instead of replacing each old light with a more efficient version, they went back to the drawing board and asked lots of questions such as:

- Do we need to have lighting everywhere?
- Do the existing lighting standards and guidelines take account of modern luminaires and LED characteristics?
- Were original design parameters applied correctly?
- Are there areas that need less lighting?

Martin McGonagle, Asset Care Head of Energy, Environment and Utilities commented on the experience of using a design-led approach for energy saving projects:

"We approach energy projects differently, and it is a good way of thinking. You begin to question everything. We have received really positive feedback from carpark operations on the new system. The new lights give a lovely bright white glow and with the touch of a button they can dim or enhance the lighting in an area. People are becoming more aware of the climate and the environment and it is important for companies to take action where they can to reduce the impact of their operations."

2.2 Luminaire replacement

Luminaire replacement involves replacing the entire fitting with a more efficient luminaire and is the most common form of lighting retrofit. This delivers greater energy savings than retrofitting lamps because the new luminaire integrates the proper wiring and control gear for the new lamp. The drawback of this approach is that the existing lighting design and layout remains the same and, without dimming controls, there is a risk of over-lighting the space.

Courtown retrofit all their internal lights

In 2016, Courtown Adventure and Leisure Centre embarked on an energy efficiency upgrade at their facility. The facility reduced electricity consumption by 32% and cost by 42%. A key success factor for the upgrade was the retrofitting of all internal lighting with LEDs.

The centre replaced a total of 385 lamps, varying from 400 W and 90 W flood lamps in the swimming pool area to various types of magnetic ballast fluorescent lamps throughout the building. They replaced all luminaires like for like with an LED equivalent, and put controls in areas with intermittent use. The facility reduced lighting energy consumption by 58% to 55,182 kWh p.a. The project had a very short payback period accelerated by grant support from the Department of Transport, Tourism and Sport.

As well as saving energy, this project had the added benefit of addressing a maintenance issue. There were 400W mercury vapour lamps lighting the swimming pool surface and 90W down-lighters illuminating walkways. These were at a height that posed problems during maintenance and replacement. The centre replaced lamps with a mixture of uplighters and downlighters around the pool's edge.

The uplighters provided reflectance from the roof down onto the pool surface ensuring adequate lighting for the pool area.

Description	Before	After
Lamp type	Mixture of fluorescent tubes, CFLs, mercury vapour lamps	LED
Wattage	385 total fittings - Range of 400 W, 90 W, 70 W, 58 W, 28 W, 18 W	200 W, 50 W, 40 W, 30 W, 20 W, 12 W
Energy consumption	95,684 kWh	55,182 kWh
Project cost	€25,177 (after grant support)	
Simple payback	3.86 years	

2.3 Lamp replacement

Most luminaires can be retrofitted with LED technology without replacing the fitting: for example, replacing a 40 W incandescent lamp with a 6 W LED lamp. Usually, the lamp connector is the same on both lamps, letting you insert the LED into the fixture. In these circumstances, you can replace lamps with more efficient ones as they fail.

However, lamp replacement does not consider the design of the luminaire and the luminaire's compatibility with the replacement. This means that the LED replacement may not work optimally with the luminaire and you may not achieve the required lighting levels.

While the impact may be unnoticeable if you are swapping out a small number of lamps for LEDs, over time, as you replace more lamps, the required lighting levels may no longer be adequate for the space.

If you are planning direct replacements across many luminaires, you should test to see if the lighting solution as a whole will meet your organisation's needs.

Considerations for fluorescent fittings

It is possible to retrofit some fluorescent fittings with LED tubes while leaving the ballast in place. In other cases, the ballast should be replaced. The approach will depend on the compatibility of the proposed LED tube with the existing ballast. Always check before installation.

When replacing fluorescent tubes with LED tubes, a replacement starter is installed, and the existing ballast remains in place. However, using an existing ballast is not as efficient as a complete luminaire replacement. This is because the lifespan of the ballast will be less than the lifespan of the LED tube - the ballast will need replacing before the lamp. Additionally, the luminaire and its sub-components, such as diffusers, may have a shorter lifespan than the new LED tube.

Where LED tubes are not compatible with retrofitting directly into fluorescent tube fixtures, you must bypass or remove the ballast and starter. If you remove the ballast, you must modify the fitting. This will increase costs, potentially compromise the luminaire electrical safety and likely cause the luminaire to lose its safety certification (CE rating). Given the risks, SEAI does not recommend or promote this approach to the retrofitting of fluorescent fittings.

Mount Carmel reduce energy use for lighting by 50%

Mount Carmel in Co. Kilkenny is a voluntary agency that provides residential services to people with low dependency needs. In 2018, with a community grant from SEAI, Mount Carmel completed a lighting replacement that included the direct replacement of seventy-three 28 W 2D CFLs, twenty single T8 70 W, eight twin T8 68W and two 12W downlight luminaires with LED replacements. The energy consumed by lighting fell from 18,054 kWh to 9,027 kWh per annum – a 50% reduction.

Description	Before	After
Lamp type	Mixed fluorescent and CFLs	LED
Wattage	73 No. 28 W, 20 No. 70 W, 8 No. 68 W, 2 No. 12 W.	73 x 14 W Ansell LED, 20 x 35 W Ansell LED, 8 x 34 W Ansell LED, 2 x 6 W LED Downlights.
Energy consumption	18,054 kWh/yr	9,027 kWh/yr
Project cost	€6,365 (after SEAI grant funding)	
Simple payback	1.95 years	

Did you know?

Traditional incandescent lamps convert most of the electrical energy into heat and a small amount into light. LEDs by contrast convert most of the electrical energy into light and a small amount into heat.

In some cases, heat gains from older lighting resulted in the need for artificial cooling, meaning further energy consumption. As such, replacing traditional lamps with LEDs may result in a marginal reduction in cooling demand, and a marginal increase in heating demand in the building.

3

Delivering Success: Implementing your lighting project

In addition to the selection of a high specification luminaire and advanced lighting controls, delivering and sustaining a successful lighting retrofit requires the following key steps:

1. **Project management**
2. **Data gathering: lighting survey**
3. **Business case development**
4. **Procurement**
5. **Installation and commissioning**
6. **Measurement and verification**

3.1 Project Management

Project management is integral to making sure each of these steps is successfully achieved. For most lighting projects, a facilities manager or in-house staff member with suitable technical expertise may be the best person to undertake the role and responsibilities of a project manager. If no one suitable is available, you may need an external consultant with the appropriate knowledge and skills to act as project manager. For larger designer or engineer-led projects, the engineer may also take a project management role.

It is critical that someone representing the client, and not the contractor, takes an ownership role in the project. If you appoint a specialist designer or engineer, they will work alongside the project manager. For large-scale projects, this may be the preferred option as the specialist will have significant experience in lighting upgrades.

The role of project manager, with assistance from any designer or engineer and lighting contractor, will include, but is not limited to, delivering the tasks in Table 5. Table 6 maps the roles associated with each stakeholder in a typical lighting project.

Table 5: Considerations before starting a lighting project

Task	Small	Medium	Large
Lighting survey and selection of lighting retrofit approach	*	*	*
Business case and cost benefit analysis	*	*	*
Financial approval		*	*
Tender preparation and evaluation		*	*
Contract award		*	*
Project delivery including installation and commissioning	*	*	*
Measurement and verification of energy savings		*	*
Operation and maintenance including training for building users		*	*

Table 6: Stakeholder roles

Stakeholder	Role
Client	Person or organisation for whom the project is being completed. The client should be identified, particularly in the case with a shared building or a leased building. The client will approve investment for the project.
Project manager	Oversees delivery of the project and ensures it is completed on time and within budget. The project manager should work for, or represent, the client.
Designer and engineer (consultant)	For larger projects a design engineer may be appointed to develop the technical specification and designs, manage procurement, and oversee/certify the project.
Lighting contractor	Appointed contractor for the delivery of the works. For smaller projects this contractor may also act as designer.
Electrician	Your local electrician may be required to provide specifications of existing luminaires or details of existing electrical systems. A registered electrical contractor of Ireland (RECI) will be required to certify the electrical installations in many cases.
Supplier	For small projects you may simply buy lights from a supplier and get your local electrician to install them.
User	It is important to consider the needs and views of the users of the lighting system – staff or customers within your facility. In addition, if occupants are responsible for switching the lighting on or off, they should be provided with information on how to use the new lighting system and controls.
Maintenance	A facilities manager or someone in-house with technical experience to provide periodic review to ensure luminaires and controls are operating, and lighting levels are maintained.

3.2 Data gathering: lighting survey

A lighting survey is a systematic review of lighting within a building. It is an investigative process that measures the existing lighting conditions against requirements to find out where you can make cost-effective changes.

It will typically include the following steps:

- Measure or estimate how much energy is being consumed by lighting in kWh;
- Review lux levels and lighting requirements of specific areas within the building;
- Analyse the condition of the lighting;
- Establish lighting energy baseline so that future performance can be measured; and
- Establish a bill of quantities for the existing lighting system.

Depending on the size of the building, the survey can range from a simple visual inspection to a more detailed analysis and redesign of the lighting. An initial walk-through inspection is a good starting point. This will help you to identify any obvious opportunities that can immediately be implemented.

3.2.1 Who should undertake the survey?

The project manager should arrange a detailed lighting survey. Who will do this depends on the size of the project, and if you have appointed a lighting designer.

The facilities manager or an in-house person with suitable technical experience can conduct the initial survey. The manager will know the operational hours. If in doubt about lamps and luminaire types, consult a RECI to identify their types and kW ratings.

Luminaire suppliers can perform a lighting survey and provide lighting design simulations and calculations. Best practice is to engage a number of suppliers through a competitive tendering process. This will ensure a suitable design that offers value for money and meets your requirements. When making final decisions, make sure to assess the suitability and independence of the supplier.

Depending on the complexity of the project, it may be appropriate to engage an independent lighting designer, or to ensure the survey is part of the appointed person's scope of works. You can engage designers to complete the survey as part of their overall scope of works. They can provide specifications for lamp and luminaire options, assist in the tender evaluation process and assess if the desired specification and energy performance is achieved.

3.2.2 Best practice for surveying

Consult SEAI's Energy Auditing Handbook while completing the lighting survey. This sets out a step-by-step approach to energy auditing including lighting. Key steps for a lighting survey include:

- Preparing a lighting audit checklist (see Table 7 for a sample checklist);
- Conducting a site survey and record findings (including photographic record);
- Consulting with relevant personnel on site;
- Analysing current lighting practices and usage – kWh and cost;
- Identifying lighting upgrade opportunities; and
- Preparing the business case.

Top tips

1. Provide useful schematics such as building layout plans and electrical wiring plans to the person undertaking the lighting survey. This will help them to navigate through the existing lighting layout.
2. Photos are an excellent way to collate information and keep records!

Table 7: Survey checklist

Task	Description
Area	*Canteen*
Area dimensions	
Area activity	
Description of the lighting	
Measurement of light lux levels	
Age of lighting system	
Lighting quality and dust accumulation	
Number of switches per area	
Control system	
Access to daylight	
Occupancy rate by staff	
Dimensions of the premises	

Area	Lamp type / Ballast	kW rating	Hours	Controls
Canteen				
Canteen				
Canteen				

As part of the data gathering process it is also important to assess:

Visual comfort

- Does the existing lamp meet the visual comfort needs of the building's occupants?
- Is there glare on computer screens or work surfaces?
- Do staff members' eyes feel strained?
- Do we need a staff survey to ascertain the level of visual comfort?

Maintenance and operation

- Are the existing lighting systems easily maintained and operated, for example if high bay lamps in warehouses fail, are they replaced or does the cost for replacement impact this?

Safety and security

- Do existing lighting systems provide sufficient light to effectively support safety, security and fire safety? Are emergency lights operating to a satisfactory level?

Top tip

Fluorescent tubes contain a magnetic or electronic ballast to regulate the voltage the lamp receives so that it will not overheat. Older models contain a magnetic ballast, while newer models contain an electronic ballast. Magnetic ballasts have an actual power rating draw 20% higher than the tube rating. You need to factor this in to your assessment. To distinguish between magnetic and electronic ballast, look at the fitting through your camera phone. If the light is flickering, then it is a magnetic ballast.

Interpret results and identify opportunities

Once you have gathered the required data to inform your lighting project you will be in a position to decide on the right lighting approach – lamp replacement, luminaire replacement or redesign.

Table 8 shows the main points to look at in assessing your readiness to develop your business case. If you answer yes to most of the questions, you should be ready to define your lighting upgrade approach and to assemble a robust business case.

Checklist 1	Identify opportunity	YES	NO
A	Can the lighting levels in certain areas of the buildings be improved?	✓	
B	Can the lighting layout design be improved?		
C	Can the number of lights be reduced?		
D	Are there lights not working that need to be replaced?		
E	Are controls required for the building?		
F	Is there a quantified potential for energy saving?		

3.3 Building the business case

A business case is an assessment of the costs and benefits (including non-financial) of carrying out a project. Depending on the scale of the project it may include life cycle costing with discounted cash flow analysis.

The target audience for the final business case document is the company manager or director of finance with the authority to approve funding for the project. Tailor the business case to their requirements so you can achieve consent to proceed with the project.

Prepare the business case in a report style format clearly laying out the case for the project, including energy savings, cost savings and non-cost savings. Table 9 outlines the main considerations for preparing a comprehensive business case. Use this skeleton as a starting point for developing your business case report.

Table 8: Business case layout

Typical business case report layout for lighting upgrade	
Executive summary	• Total energy consumption – electricity (kWh) and thermal (kWh). • Existing lighting consumption (kWh and €). • Lighting upgrade savings (kWh and €). • % of total electricity savings (kWh and €). • Energy and CO_2 targets and statutory requirements. • Brief description of existing installation. • Brief description of proposed upgrade.
Introduction	• Background – why you want to change. • Description of existing – is it outdated? Is it meeting the lighting requirement? Lamps which are no longer working etc. • Essential works – list works that need to be completed either because lamps are not working or for health and safety reasons.
Proposed upgrade	• Description of the proposed upgrades including table with proposed lighting changes. • Benefits – energy and non-energy benefits. • Other considerations – proposed installation times. • Risks associated with upgrade. • Monitoring requirements.
Financial analysis	• Capital cost, maintenance cost. • Available grants and supports including energy credits. • Cost savings and payback – separate energy and maintenance savings – include discounted payback period for larger projects.
Next steps	• Financial approval. • Allocate resources to implement project. • Set out project timeline.

3.3.1 Cost and payback

Cost will play a big factor in determining the success of your business case. Talk to those who will approve the project and ask how they want the financial model presented. There are several ways to present the financial model, as shown below.

Simple payback is the length of time required to recover the cost of an investment. For example, a lighting project has a capital cost of €100,000 and annual savings of €40,000.

$$\text{Simple payback} = \frac{\text{Project investment cost}}{\text{Annual savings}} = \frac{€100{,}000}{€40{,}000} = 2.5 \text{ years}$$

Present value (PV) is the current value of a future sum of money or stream of cash flows given a specified rate of return. Future cash flows are discounted at the discount rate, and the higher the discount rate (r), the lower the present value of the future cash flows. For example, the present value of €40,000 that would be paid after five years would be:

Net present value (NPV) is the difference between the present value of cash inflows or savings and the present value of cash outflows over a period of time.

For example, if a lighting project costs €100,000 and the proposed savings are €40,000 per year for five years and a discount rate of 15% is used, then the net present value is (see table 9):

$$\text{Present value} = \frac{\text{Future value}}{(1+r)^n} = \frac{€40{,}000}{(1.15)^5} = €19{,}887$$

Table 9: Net present value

Year	Cash flow (€)	Present value (€)	Net present value (€)
0	-100,000	-100,000	-100,000
1	40,000	34,783	-65,217
2	40,000	30,246	-34,972
3	40,000	26,301	-8,671
4	40,000	22,870	14,199
5	40,000	19,887	34,086

The year when the discounted savings equal investment costs equals the discounted payback period. At year four the net present value is positive, so the project has realised savings. For a five-year project, a negative net present value at year five would mean the project does not make financial sense. Net present value is an example of a discounted cash flow method. Public sector projects have a discount rate between four percent and eight percent, whereas private sector projects often have higher discount rates.

Internal rate of return (LRR) is another method used to measure the profitability of a project. This is the rate of return on a project that makes the net present value equal to zero. If this is greater than the discount rate, the project is worthy of consideration.

Life cycle cost (LCC) is the sum of the net present value of all the costs – investment costs and operational costs (energy, spare parts, labour etc.) – over the lifetime of the project. Traditionally the net present value of a project compares the investment cost (negative) against the energy and maintenance savings (positive) to see if the savings outweigh the investment costs over time. With life cycle cost, both the investment costs and the ongoing costs are negative, so the result is always negative. This method is used to compare different investment options with the most attractive option generally being the one with the lowest life cycle cost.

Table 10: Life cycle costs

Costs (€)	Year	Project 1		Project 2	
		Cash flow (€)	Present value (€)	Cash flow (€)	Present value (€)
Investment	0	100,000	100,000	125,000	125,000
Running Cost	1	65,000	56,522	55,000	47,826
	2	65,000	49,149	55,000	41,588
	3	65,000	42,739	55,000	36,163
	4	65,000	37,164	55,000	31,446
	5	65,000	32,316	55,000	27,345
Life Cycle Cost			317,890		309,368

Further guidance on completing a financial assessment of your project is available in the SEAI Energy Audit Handbook, Chapter 6: Financial Analysis of Opportunities

Grants, supports and financial incentives

Consult the SEAI website for relevant grants, supports and government incentives that can help you deliver your project, including the Accelerated Capital Allowance (ACA). This tax incentive promotes investment in energy-efficient products and equipment. It allows a sole trader, farmer or company that pays corporation tax in Ireland to deduct the full cost of the equipment from their profits in the year of purchase.

3.4 Procurement

Following investment approval, your organisation will be prepared to begin the procurement process. Whether you are a public or private sector organisation, it is advantageous to undertake a competitive tendering process to ensure that you get value for money.

When setting out your timeline for project delivery, set aside an appropriate amount of time for procurement. This is particularly relevant to public sector organisations, which are obliged to procure goods and services under public procurement regulations. The Office of Government Procurement provides information, templates, and guidance on public procurement.

Of particular interest to public bodies is the Public Procurement Guidelines for Goods and Services, available to download on the Office of Government Procurement's website. This outlines the procurement steps associated with each tendering threshold (national and EU) on goods and services. Most lighting projects will be within the national thresholds.

3.4.1 Lighting specifications

Lighting specifications will set out the requirements for your lighting project and should be agreed before any work or procurement starts. The lighting specification is included in the invitation to tender or request for quotation documentation to ensure that each tenderer is quoting for the exact same system.

The specification will be informed by the lighting survey and may include:

- A schedule of existing lighting at your building or facility.
- Identification of lux level requirements for different areas within the buildings.
- Minimum energy performance and quality criteria for the lighting products, for example luminous efficacy, colour rendering, temperature and consistency, controls, life expectancy etc. (See Section 1 of this guide for further details.)
- List of lamps to be retrofitted or replaced (see Table 11).
- Short description of lighting requirements for each area.
- Controls – existing, occupancy, daylight or microwave sensors, dimming vs switching, DALI.
- The design plan, if one is required for the project (e.g. for new designs completed by a specialised lighting contractor).
- The required specifications for the new lamps or luminaires.
- Floor plans and layout of existing lighting system.
- Electrical wiring diagrams of existing lighting system.
- Lighting bill of quantities (sample provided in Table 11).
- Performance data for all lamps and luminaires that will be installed as part of the contract.
- Lighting design if complete.
- Energy consumption and savings.
- Details relating to maintenance, repair, recycling – including training if applicable.
- Warranty and spare part availability.

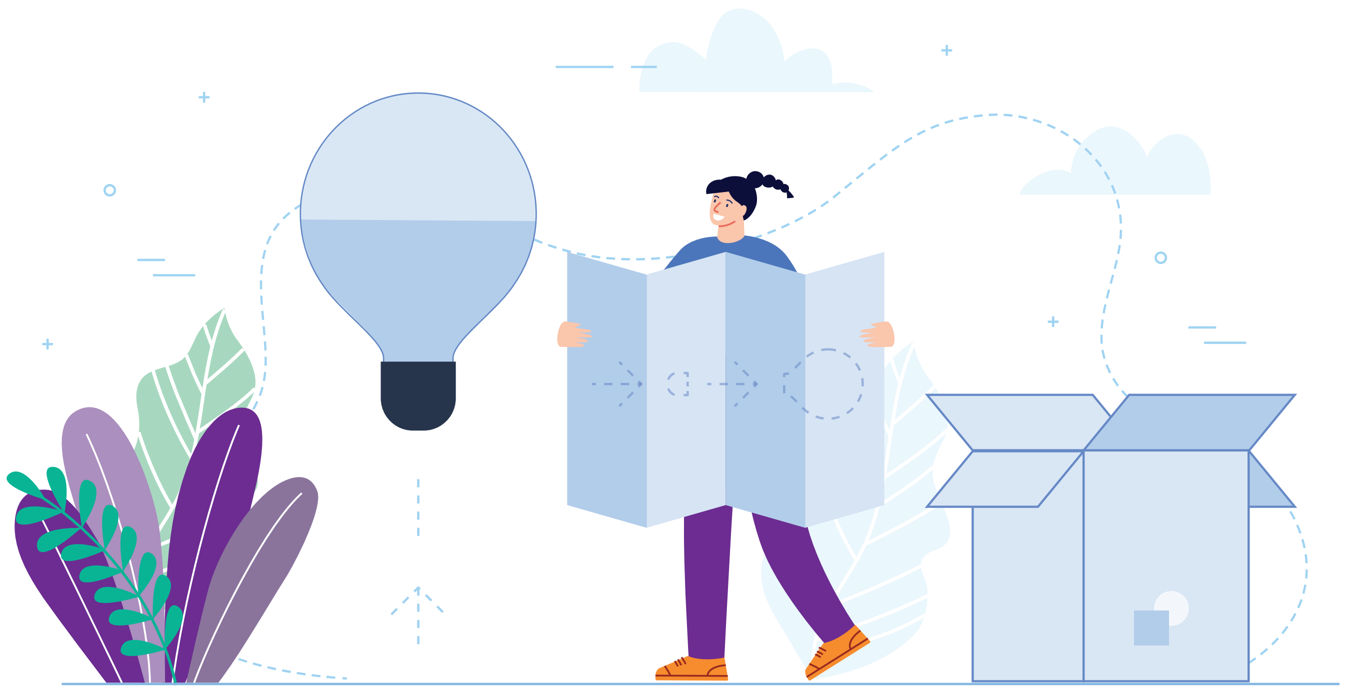


Table 11: Sample schedule of existing and proposed lighting

	Bill of Materials – Building X (ex. VAT)			Proposed Fitting (ex. VAT)				Unit Costs		Total Cost	
	Existing Fitting Description	Mounting	Quantity	Make & Model	Triple E Ref.	Lumen Output	Full Fitting Watts	Materials	Labour	Materials	Labour
1	T8 4' twin IP65	Surface	25								
2	T5 600x600 4 lamp panel	Recessed	130								
3	T8 (HE) 600x600 panel 4 lamp	Interlocking c. tiles	120								
4	2D 28W c/w inverter pack	Surface	12								
5	PL Downlighter (1x18W)	Recessed	25								
6	PL/CFL lamp 18W	Lamp Only	13								
7	Integrated emergency pack	Recessed	85								
8	PIR c/w IR receiver	Recessed	20								
9	400W High Bay	Bracket	5								

Note: Existing fittings are informed by your lighting survey. Proposed fitting and costs will be populated by contractors as part of their tender return.

3.4.2 Procurement options

There are several contracting options for procuring a lighting project. Traditionally projects seek quotes weighted favourably towards price, with some thought given to quality and experience. However, this method typically falls short in managing the risk of the energy savings not materialising. To avoid this, consider incorporating energy efficiency into your scoring mechanism, or look beyond the traditional method and consider incorporating a pay-for-performance element.

Traditional approach

With the traditional procurement approach, the client carries out most of the preliminary work (with or without the assistance of external consultants) and commits the financial resources. The contractor is appointed to complete the project and payment is made when it is complete. There is often no follow-up to ensure savings are achieved. However, follow-up can and should be built into the project requirements, depending on its scale.

Traditional procurement using the most economically advantageous tender (MEAT) evaluation method generally considers price, methodology, approach and experience of delivering a project of a similar scope as selection criteria. However, you can structure the scoring to promote the most energy efficient option. Ensure emphasis is proportionate to benefit – don't pay a premium that exceeds life cycle savings.

Lighting as a service

Several companies in the Irish market offer variations of the 'lighting as a service' (LaaS) model. Contractual approaches vary but generally take the form of a services contract, lease finance arrangement, or a hire purchase arrangement.

Most of these models do not see the contractor take any performance risk beyond technical failures of the equipment. The expected savings, and therefore payments, are generally based on an engineering calculation presented to the client as part of the sales and tendering process.

For lighting retrofit projects, the risk of any savings not materialising is very low – but the level of savings stated may not happen if they have been miscalculated. If possible, it should be a condition of the contract that the contractor takes at least part of the energy performance risk.

Main benefits:

- Contractor takes medium term technical risk (of failure);
- Contractor finances the project (for example, monthly re-payment instalments over five years);
- Lighting is surveyed and upgraded by the contractor; and
- Contractor will provide expert services to assess, deliver and maintain (for a predetermined period) your lighting project.

Top tip

Typically lighting as a service contracts do not guarantee performance and, if savings do not materialise, you have little contractual recourse.

Make sure to validate the calculation of savings provided in quotations or have them checked by an independent expert. Where possible, include energy performance criteria into your tender specification and/or contract agreement.

Pay-for-performance approach

- **Energy performance guarantee**

An energy performance guarantee is a basic arrangement for energy performance. It can and should be considered for all energy saving projects. It includes a guarantee that energy savings will materialise.

In a typical energy performance guarantee, the client pays the capital cost, but part payment is retained for a period of time until the savings are demonstrated. In this case it is essential to monitor lighting energy consumption before and after the lighting project is commissioned.

- **Energy performance contracting**

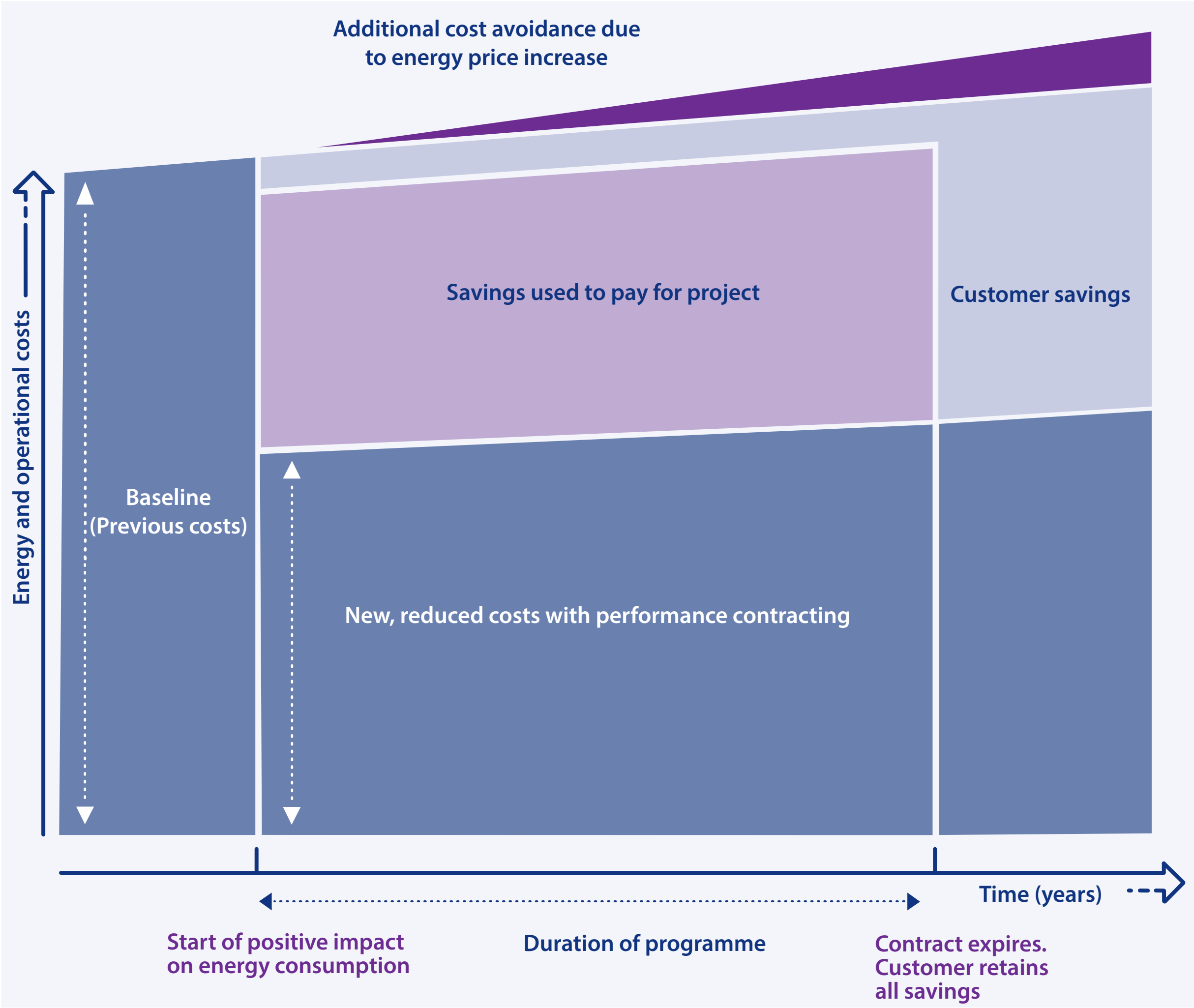
An energy performance contract (EPC) is a contract where payments are related to the performance of the investment against a guaranteed level. These contracts take numerous forms, but they all share a method of incentivising a guaranteed performance based on the contractor taking a financial risk for that performance. The project may or may not be financed by the client or a third party. Figure 15 illustrates the concept of energy performance contracting.

Main benefits:

- Energy savings are guaranteed;
- Contractor takes energy performance risk;
- Contractor manages plant operation and maintenance, freeing-up client resources; Contractor takes medium term technical risk (of failure); and
- Optional contractor or third party finance for the project.

In both energy performance guarantees and energy performance contracting, savings are measured and verified to ensure guaranteed savings are achieved. Depending on the guarantee or contract arrangement, if the savings fall short of the agreed amount, the vendor loses a part or all of a performance payment. See section 3.6 for explanation of the measurement and verification process.

Figure 15: Energy performance contracting



Further information on energy contracting, and how SEAI can support you to use this approach to deliver your project, check out the SEAI website: **www.seai.ie/energycontracting**

3.5 Installation and commissioning

It is important to complete an installation checklist with the installer once the project has been commissioned. If no is answered to any of the questions in checklist 2, ensure the installer takes corrective action before final payment is made.

Checklist 2	Installation checklist	YES	NO
A	Complete visual inspection with installer. Are all luminaires installed?	✓	
B	Are automatic and manual controls working? Test all controls with the installer.		
C	Are you happy with lighting levels? If not, ensure corrective action is taken by the installer.		
D	Are downlights adjustable? Make sure they are adjusting to suit your needs.		
E	Are lamps extending down beyond the downlight apertures? If so, ensure corrective action is taken by the installer.		
F	Is the colour temperature correct? Where there are multiple lights, ensure that the same colour is used.		
G	Is the emergency light working? Has commissioning and certification been completed?		

It is important to request a commissioning and handover file from the installer once the project has been commissioned and you are happy with the installation.

Checklist 3	Commissioning and handover file checklist	YES	NO
A	Schedule of lighting fitting – include manufacturer, fixture type and model number, and lamp / wattage details	✓	
B	Site layout plan of new lighting installation		
C	Safe electric and emergency lighting and emergency lighting certificates supplied.		
D	Operation and maintenance (O&M) manuals and warranties		
E	Staff training complete		

Staff working in your building must be made aware of the operational changes to the lighting arrangements. They should be informed that this is an energy-saving exercise and that the changes will improve the lighting levels and controls within the building.

As part of the handover file, ensure you provide staff with training that shows them how to use, and how not to use, the new lighting system.

3.6 Performance measurement and verification

Measurement and verification (M&V) is the process of planning, measuring, collecting and analysing data for the purpose of verifying and reporting energy savings resulting from the implementation of an energy saving project. Savings cannot be directly measured, since they represent the absence of energy use. Instead, savings are determined by comparing measured consumption before and after the project is implemented, making appropriate adjustments for changes in conditions.

Savings = Baseline period energy – Reporting period energy) ± Adjustments

There are four M&V approaches/options under the International Performance Measurement and Verification Protocol (IPMVP) However lighting projects usually follow these two options:

Retrofit isolation – key parameter measurement

- Savings are determined by field measurement of the key performance parameter(s) to display the success of the project.
- Estimates can be based on historical data, manufacturers' specifications or engineering judgement. For example, in a lighting retrofit the power draw is measured periodically and lighting hours are estimated based on facility schedules and occupancy behaviour.

Whole facility

- Savings are determined by measuring energy consumption at the whole facility or sub-facility level.
- Continuous measurements of the entire facility's energy use are taken through the reporting period.
- Savings are calculated by analysing the whole facility baseline and reporting period using utility meters or sub-meters over the whole facility or a major part of it.
- This option determines the joint savings of all energy efficiency upgrades applied. Routine adjustments are required using simple comparison or regression analysis. For example, measure energy used with gas and electric utility meters for a twelve-month baseline period and throughout the reporting period.

Top tip

If you intend to use performance contracting and the International Performance Measurement and Verification Protocol, it is very important to establish at pre-contract stage the full process to be followed, baselines to be used, and variables to be applied. Clear, pre-agreed measurement and verification processes are critical to a successful performance contract.

4

Lighting standards and safety

4.1 Lighting standards and safety

Your registered electrical contractor (RECI), installer and lighting designer must ensure that all works meet the current lighting and safety standards. This applies throughout the design, specification and installation phases of your project.

Relevant lighting standards for your project include:

EN 15193 Energy performance for buildings – Energy requirements for lighting

This defines the energy performance of the building on an annual basis using the LENI calculation. LENI = W/A (kWh/m^2) where W is annual kilowatt hours consumed and A is the total useful floor area. Target values are specified.

EN 1838:2013 Lighting appliances – Emergency lighting

This describes the photometric properties that need to be met for emergency lighting and specifies the minimum uniformity of the emergency lighting.

EN 12 464-1:2011 Light and lighting – Lighting of work places, Part 1: Indoor

EN 12 464-2:2014 Light and lighting – Lighting of workplaces, Part 2: Outdoor

These standards specify requirements for lighting solutions for most indoor or outdoor work places in terms of quantity and quality of illumination.

4.1.1 CE Markings

CE marking on a product is a manufacturer's declaration that it complies with the relevant European health, safety and environmental protection legislation. All lighting products used in your project should have CE markings and should come with a declaration of conformity from the manufacturer. Note that the CE label indicates that the lamp or luminaire complies with safety standards. It does not indicate conformity with performance standards.

4.1.2 Emergency lighting

Emergency lighting is a crucial element of a building's lighting system. The objective of emergency lighting is to enable safe exit from anywhere in a building in the event of the normal electrical supply failing.

Emergency lighting must, by law, be maintained and tested on a regular basis.

EN1838:2013 is the European Standard for emergency escape lighting and standby lighting systems. Together with IS3217:2013, it sets out a range of considerations, including the number and positioning of emergency lights, lux levels and the competency of those responsible for lighting design and installation. It also covers design, installation and commissioning certification.

> Section 5.1 of this guide provides further guidance on emergency lighting for your retrofit project.

4.2 Electrical safety

Safe Electric Ireland is the statutory regulatory scheme for electrical contractors. Its role is to ensure that all registered electrical contractors operate to the relevant national standards and technical rules.

In general, a registered electrical contractor is required to sign off and certify the electrical works on lighting upgrades in existing properties. With a retrofit, the works involved could be defined as 'controlled electrical works', 'restricted electrical works' or 'minor electrical works'. The registered electrical contractor must complete and test all works to the relevant national standards and will issue you with a Safe Electric Certificate of Completion to confirm this. Specifically, this certifies that the works completed to an existing installation do not impair the safety of that installation, or that the safety of the new installation is not impaired by the existing installation.

When completing a lighting upgrade, check with Safe Electric to see if you need a registered electrical contractor. There are some instances when one is not required – specifically, where no wiring or electrical works are carried out. This may be the case on a small like-for-like lamp replacement project. While this must also be in compliance with the National Rules for Electrical Installations (currently ET101:2008), these types of electrical works sit outside the defined scope of 'controlled electrical works' and 'restricted electrical works' as defined by the Commission for Regulation of Utilities (www.cru.ie).

For all other upgrades, a registered electrical contractor should be employed. The Health and Safety Authority provides a useful list of works where electrical work requires certification, but SEAI advises that you consult with Safe Electric or a registered electrical contractor to ensure your installation is compliant.

A residual current device and circuit protective conductor are life-saving devices designed to prevent you from a fatal electric shock if you touch something live, such as a bare wire.

Your registered electrical contractor is required under the Safe Electric scheme to test these protective devices in new or modified installations. This is to ensure the new works have not impaired the safety of the existing installation. Registered electrical contractors must certify and verify earthing arrangements and earthing conductors throughout the distribution system in the building.

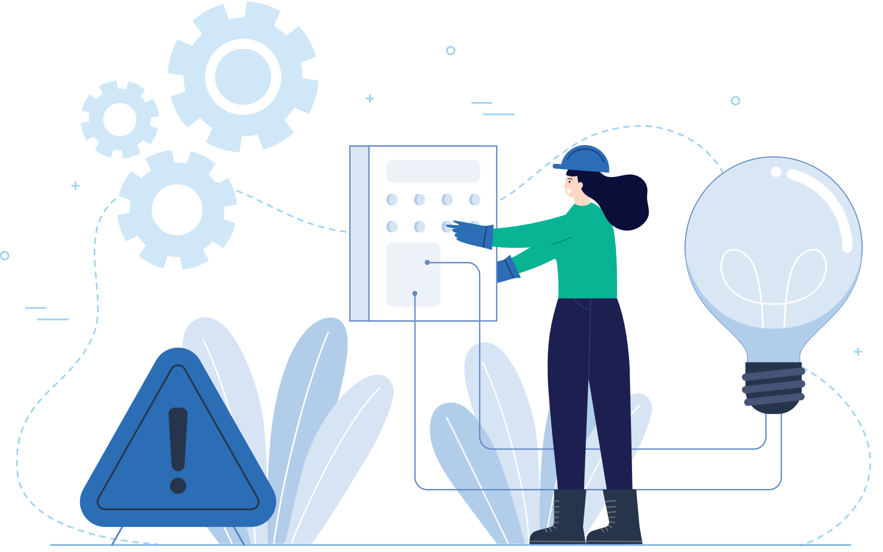
> **Top tip**
>
> Always request a Safe Electric Certificate of Completion from your contractor when the lighting upgrade is complete. Ensure that all sections are completed correctly.

4.3 Earthing

Many lighting circuits (usually older buildings) may still be in use with no earthing, or may use metal conduit as the earth return path. This type of circuit may present challenges for your installation.

For example, the circuit may not meet current standards and, to be certified by a registered electrical contractor, will require an upgrade. Also, the circuit may not allow certain lighting controls to be installed.

For older buildings it is always worth engaging with a registered electrical contractor early in the process of assessing a lighting retrofit. This will establish whether any deeper upgrade of electrical distribution and protection is required.



5

Other lighting applications

5.1 Emergency lighting

When carrying out a lighting upgrade, it is essential to think about emergency lighting, particularly if the building layout has changed over the years. This may have made the current emergency lighting arrangement unfit for purpose.

Additional benefits of upgrading to LED emergency lighting include superior lighting performance, cost and energy savings through improved efficiency, reduced maintenance and the chance to remove unnecessary lighting with a redesign.

Emergency lighting is essential for the safety of the building and the staff occupying it. Building owners are legally obliged to ensure their emergency lighting systems are installed and operate to the relevant standards. Current regulations state that quarterly inspection and annual testing of the emergency lighting system must be completed, and a record kept. When undertaking lighting projects, consult a suitably qualified electrical engineer or electrician to ensure that you are meeting your legal obligations for emergency lighting.

Typical options for emergency lighting during an overall lighting retrofit are:

- Keeping the existing emergency lighting luminaires and system. Existing certification will not change.
- Replacing existing emergency lighting luminaires on a like-for-like basis. Existing certification may suffice – consult your registered electrical contractor or design engineer.
- Installing a new emergency lighting system. This will require full certification to IS3217:2013.

The Irish Standard for Emergency Lighting IS 3217:2013 and Amendment 1:2017 promotes a wider understanding of the different types of emergency lighting systems and modes of operation. It gives guidance on their correct application, in accordance with legislation, building regulations and European standards.

In many existing installations the emergency lighting is integrated or self-contained within the standard luminaires. Recent trends have seen a move towards independent emergency fittings which only operate when required.

Figure 16: External LED façade lighting

Self-contained luminaire system

The most common and cost-effective form of emergency lighting in new installations is a self-contained low wattage recessed LED downlight ('pin spot') with integrated battery pack designed to illuminate only in an emergency. Bulkhead emergency lights with integrated battery packs are commonly used. There are also twin bulkhead emergency lights used in larger applications. As these lights operate only in emergencies, their reliability is much more important than their efficiency.

Integrated emergency luminaire system

In an integrated emergency system all elements of the luminaire – battery, lamp, control unit and any monitoring facilities – are contained within the luminaire itself, which operates as a normal luminaire during regular operations. Integrated emergency luminaires are not as common in new installations, but many retrofits use them for simplicity.

As they are more expensive than an equivalent non-emergency luminaire, it is more common, particularly in new installations, to use a recessed pin spot emergency luminaire.

Centralised power system, using centrally supplied luminaires
A central power system is an emergency lighting system, compliant with I.S. EN 50171. It distributes an emergency electrical supply from a central battery unit. The central power system can be powered from a central battery system, static inverter system or uninterruptible power supply.

Central generator powered
A central generating system shall be of the mains failure automatic-start type. Generating systems that are not capable of being placed on load within five seconds shall be supplemented by a battery system to provide sufficient power to operate the emergency lighting system.

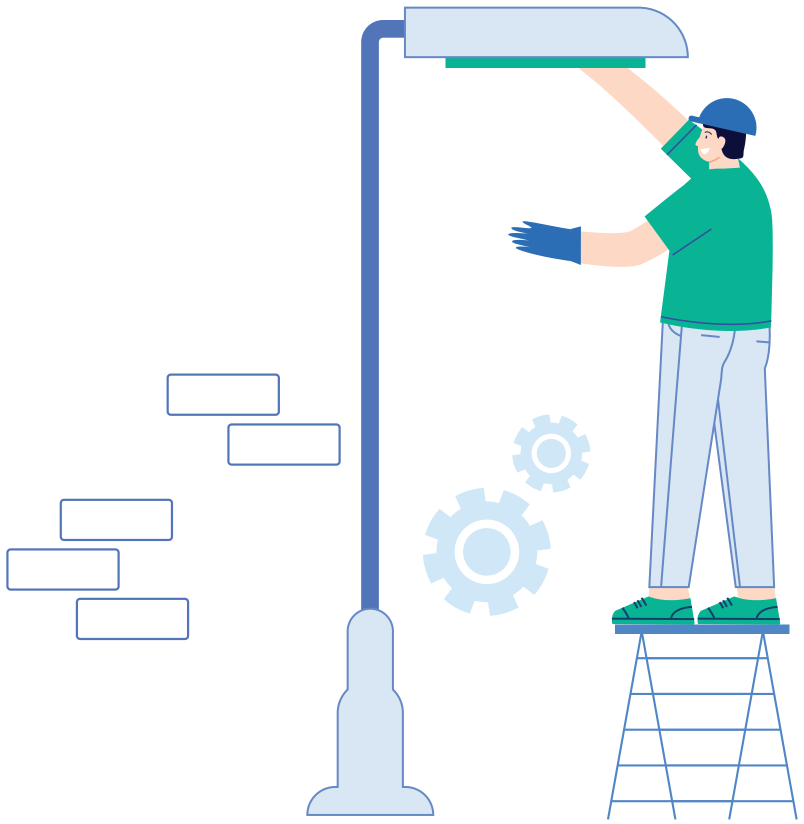
5.2 External lighting

External lighting is used for safety and security and to improve a building's appearance. In some facilities, external lighting will be required through the night, and, with poor controls, these may not turn off when they are not required the next morning. Energy efficient exterior lighting and controls will save energy and reduce light pollution.

The smaller size of LEDs makes them ideal for enhancing building aesthetic. Exterior luminaires are usually sealed units to protect them from water damage, so retrofitting more efficient lamps is not always viable.

For most applications, external luminaires come in two distinct types: lanterns and floodlights. Exterior LEDs used in carparks and around buildings can be easily switched on and off, and can be used with motion and daylighting sensors or timers. In contrast, high pressure sodium and metal halide lamps take a long time to reach full output.

To get the full benefit of a lighting retrofit, it is best to think about external lighting at the same time as the internal lighting. For example the external façade lighting in Kilkenny County Hall was upgraded in 2014 during a larger internal lighting retrofit project. SON lanterns were replaced with low wattage LEDs. They significantly reduced the running costs and improved the quality of the building's façade lighting.



Appendices

Appendix A - References

Carbon Trust, 2012. How to Implement External Lighting. [Online] Available at: https://www.carbontrust.com/media/19559/ctl162_how_to_implement_external_lighting.pdf [Accessed May 2019].

Carbon Trust, 2012. How to Implement Lighting Contols. [Online] Available at: https://www.carbontrust.com/media/31642/ctl161_how_to_implement_lighting_controls.pdf [Accessed May 2019].

Carbon Trust, 2012. How to Implement Lighting Refurbishments. [Online] Available at: https://www.carbontrust.com/media/32080/ctl163_how_to_implement_lighting_refurbishments.pdf [Accessed May].

Carbon Trust, 2018. Lighting: Bright Ideas for Efficient Illumination, London: Carbon Trust.

CIBSE, 2018. Society of Light and Lighting: Lighting Handbook, London: Chartered Institute of Building Services Engineers.

European Commission, 2015. A Consumer's Guide to Energy Efficient Lighting. [Online] Available at: https://ec.europa.eu/energy/sites/ener/files/documents/fin_2_consumer_guide_-_lighting_en.pdf
[Accessed May 2019].

European Commission, 2015. Phase-out of inefficient lamps postponed to 1 September 2018. [Online] Available at: https://ec.europa.eu/energy/en/news/phase-out-inefficient-lamps-postponed-1-september-2018
[Accessed October 2018].

NSAI, 2014. Irish Standard I.S. EN 16247-2:2014 Energy Audits - Part 2: Buildings, Dublin: National Standards Authority of Ireland.

Premium Light Pro, 2017. Indoor Lighting in the Public and Private Service Sectors, Copenhagen: Energy Piano.

Premium Light Pro, 2017. Procurement criteria for LED indoor lighting in the service sector. [Online] Available at: http://www.premiumlightpro.eu/fileadmin/user_upload/Guidelines/Procurement_Criteria_Indoor.pdf
[Accessed October 2018].

Pryde, J. R., Whalley, D. C. & Malalasekera, W., 2014. A review of LED technology trends and relevant thermal management strategies. Floria, Institute of Electrical and Electronics Engineers (IEEE).

SEAI, 2017. Energy Audit Handbook, Dublin: Sustainable Energy Authority of Ireland.

SEAI, 2018. SME Guide to Energy Efficiency, Dublin: Sustainable Energy Authority of Ireland.

Appendix B – Common challenges

Challenges	Details and potential solutions
Picking a lighting specification	Consult with several suppliers. Consider the Office of Public Works Lighting specifications for offices presented in Section 1. This specification may not be right for your project, but the main elements of a performance specification will follow this format and you can discuss with suppliers the cost impact of various specification levels.
Forecasted savings not materialising	When energy savings are presented, running hours may be exaggerated resulting in higher than realistic savings. You should always understand the lighting requirement of your building and confirm what is being presented represents your building. Ideally you should measure the lighting run hours in each area to ensure you have an accurate reflection of energy use.
Incidental or 'attendant' costs	When a capital cost for a project is presented, it may not include hidden costs such as replacing ceiling tiles, moving electrical components, repainting, etc. Ensure the quote includes the full cost to supply, install and commission the project. Ensure you provide time for the contractor to complete a full survey of the building before submitting the quote, and that the scope of supply includes remedial works and making good.
Emergency light fittings	When completing a lighting upgrade, emergency lighting can sometimes be overlooked – particularly where the small LED that identifies them has moved out of sight. Fittings with an integral emergency pack could then be replaced by standard fittings. Ensure that you get access to the emergency lighting drawings or schedules and ensure your contractor checks each fitting as it is removed. Ensure emergency lighting certification is provided where required.
Emergency lighting not fit for purpose	Emergency lighting may not be fit for purpose as buildings may have been designed for different functions and office equipment may have been re-located. Emergency lighting regulations have also become more rigorous in recent years. It generally makes sense to address any inadequacies in emergency lighting when completing your overall lighting project. You should request a separate quote to upgrade emergency lighting to current standards.
Low quality fittings	Although LED lighting has significantly improved in recent years, there are still poor-quality products being sold. SEAI Triple E lighting products have best in class efficiency and meet all the required standards. Request evidence that the lighting product meets Triple E or equivalent standards.

Challenges	Details and potential solutions
Electrical upgrades	Current regulations require light fittings to be properly earthed, but this may not have been done in older installations. Seek the advice of your electrician and factor any associated costs into your analysis.
Decorative, bespoke or feature lighting	These can be expensive to retrofit or replace as specialised fitting may be required. Hours of operation need to be considered as it may not always be cost effective to replace.
Different form factors for replacement fittings	LED downlighters are generally a smaller diameter than compact fluorescent fittings. Ensure adaptor collars are available to allow the smaller fitting to fill the existing opening without the need for expensive modifications to the ceiling. In some cases, ceiling tiles may need to be replaced. Ensure that this is included in the quote as an additional cost.
Daylight sensors and movement detection sensors	Ensure daylight sensors and movement detection sensors meet the requirements of the building. For example, daylight controls allow lighting to be switched, however, in the interest of safety it may be required that the lights remain on. Discuss your lighting requirements with your installer.
Building occupants and behaviour	When occupants have been in a poorly lit environment, they may perceive a new LED installation as being overly bright. Light readings should be taken before and after the installation to show that light levels are now in line with norms. Good lighting controls can allow occupants to set the lighting to lower levels where required.
Location of sensor	Ensure sensors are placed in appropriate areas. For example, in a bathroom where sensors have been placed over cubicles meaning that lights do not turn on when someone enters the room. This is poor and unsafe practice.
Measurement and verification of projects	Ensure that key baseline information on electricity consumption and run hours is collected before the project starts. If occupancy hours change after retrofit, this should be taken into account in measurement and verification.

Appendix C – Sectoral guides

LED lighting for warehouses

Many luminaires in industrial settings and warehouses are positioned at heights, and if a warehouse has been reconfigured in some cases the lights can be in the wrong places. When completing a lighting upgrade in warehouses, consideration must be given to the positioning of luminaires, the activities they are lighting, and ease of access for maintenance.

Warehouse lighting – constraints and opportunities

Constraint or opportunity	Guidance
Maintenance	LEDs' longer life will reduce maintenance costs particularly in high bay areas.
Luminaire design	Good reflector design will improve lighting distribution.
Paint surfaces	Paint surfaces (including ceilings) with matt colours of high reflectance. Bright colours can reflect up to 80% of incident light.
Zone controls and over lighting	Split building into zones which can be separately controlled either manually or automatically, for example by presence detection or time-clock.
Skylights	Skylights are a good opportunity to offer free daylighting. Keep skylights clean.
Daylighting controls	Install daylighting controls in areas with access to natural light.
Presence controls	Use long range microwave detectors to switch lights on only when aisles are being used.
Colour temperature	4000K to 5000K are best suited for warehouse application. These emit a blue white which can help reduce eye strain.
Replacement of lamps	Can be more costly if lamps are only replaced as they fail. Consider re-lamping all luminaires at once.

LED lighting for offices

The correct luminaire specifications and location in an office environment can help staff to perform their work efficiently without eye strain or fatigue. When completing lighting upgrades in offices, consideration must be given to the positioning of luminaires for task lighting and daylighting controls in offices with glazing.

Office lighting – constraints and opportunities

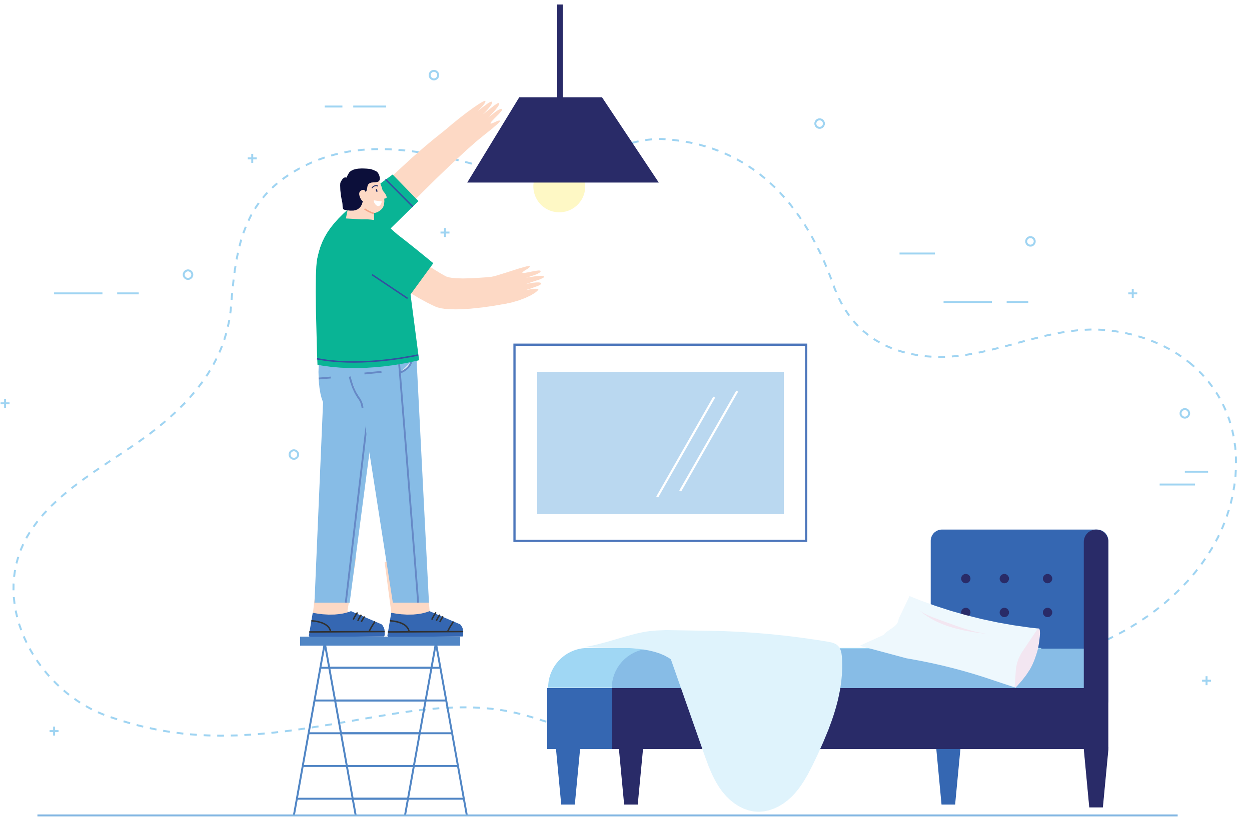
Constraint or opportunity	Guidance
Maintenance	LEDs' longer life will reduce maintenance costs and disruption in the office environment.
Luminaire design	Good reflector design will improve lighting distribution.
Cooling and heating load	Energy efficient luminaires produce less heat which means less mechanical cooling is required to maintain working conditions. There may, however, be a slight increase in heating load.
Office plan layout	Make an office plan and select the optimal lighting solution based on the different tasks in each area.
Shadows on work plane	Task lighting should be placed in front of the user's line of vision.
Correct lighting levels	Areas may be illuminated by general lighting or dedicated luminaires. A higher work plane illumination is better for the occupant's eyes and attention is automatically drawn to areas with more light. Reduce light levels in non-task areas to reduce energy consumption.
Glare on display screens	Considered placement of display screens will reduce glare from windows and allow blinds to be kept open to maximise daylighting. Screens should be perpendicular to the windows to avoid mirroring of windows in screens and high contrast to the outside view.
Over lighting	Now that office work is predominantly computer based the traditional 500 lux requirement no longer applies: 300 lux is generally sufficient for most modern offices and can save considerable energy.
Automatic controls	One of the biggest wastes of energy in offices is lights being left on when there is sufficient daylight or when the room is unoccupied. This can be reduced by installing daylight and pres-ence sensors.
Replacement of lamps	Costly if lamps are only replaced as they fail. Consider re-lamping all luminaires at once.

LED lighting for hotels

Lighting typically accounts for nearly a third of electricity consumed in hotels. Hotels have lobbies, corridors and staircases which customers must navigate, so it is essential that these areas are sufficiently illuminated. When completing a lighting upgrade in hotels, consideration must be given to luminaire positioning and maintenance, with a particular emphasis on the comfort of occupants.

Hotel lighting – constraints and opportunities

Constraint or opportunity	Guidance
Maintenance	LEDs' longer life will reduce maintenance costs and minimise disruption to guests.
Luminaire design	Good reflector design will improve lighting distribution.
Cooling and heating load	Energy efficient luminaires produce less heat. This means less mechanical cooling is required to maintain working conditions. There may, however, be a slight increase in heating load.
Paint surfaces	Paint surfaces (including ceilings) with matt colours of high reflectance. Light colours can reflect up to 80% of incident light.
Automatic controls	Hotel corridors and toilets are often empty for a large part of the day and night and significant savings can be made with presence controls.
Colour temperature	3500K creates a warm inviting atmosphere that is ideal for hotels and the hospitality sector.
Maintenance and replacement lamps	Costly if lamps are only replaced as they fail. Consider re-lamping all luminaires at once.



LED lighting for retail

Lighting accounts for a large portion of electricity consumed in retail stores. Good lighting can direct attention to goods and guide customers through aisles. When upgrading the lighting, consider the luminaire specification, location and zoning.

Retail lighting – constraints and opportunities

Constraint or opportunity	Guidance
Maintenance	LEDs' longer life will reduce maintenance costs.
Luminaire	Good reflector design will improve lighting distribution.
Cooling and heating load	Energy efficient luminaires produce less heat. This means less mechanical cooling is required to maintain working conditions. There may, however, be a slight increase in heating load.
Zoned lighting	Divide large stores into different lighting zones depending on activity.
Zoned controls	Segregate circulation, maintenance and security lighting from display lighting so that the circuits can be controlled separately.
Automatic controls	Use presence detection in storerooms, staff areas, toilets and for external security lighting.
Time control	It is not necessary to have the same lighting level during re-stocking as during trading hours. Use time clocks to switch off circuits or dim lights during these times.
Colour temperature	3500K creates a warm inviting atmosphere ideal for the retail sector.

Appendix D - Glossary of terms

Absence detection: A type of control that automatically switches the light off, or dims it down, after the space becomes unoccupied, but where switching on is done manually.

Ballast or control gear: Part of the control equipment of fluorescent or discharge lamps to stabilise the current.

CE: 'Conformité Européene', meaning European Conformity', is a declaration of quality and compliance.

CEN: European Committee for Standardisation.

CENELEC: European Committee for Electrotechnical Standardisation.

Circuit-watt: The power consumed in lighting circuits by lamps and, where applicable, their associated control gear (including transformers and drivers) and power factor correction equipment.

Colour rendering index (CRI): An international system used to rate a lamp's ability to render object colours. The higher the CRI (based upon a 0-100 scale), the better colours appear.

Colour temperature: Different light sources produce different coloured light known as the colour temperature. This is measured in Kelvin (K).

Compact fluorescent lamps (CFLs): A high efficiency lamp using an electric discharge through low pressure mercury vapour to produce ultraviolet (UV) energy, which in turn produces visible light.

Control gear: A ballast or driver is described as the control gear.

Dimmable addressable lighting interface (DALI): A two-way communication system that provides a single interface for all electronic controls gear (lamps) and electronic control devices.

Discharge lamps: Lamps that produce light by discharging an electric current through a gas (neon, argon, krypton) or a gas/metal vapour mixture (mercury, sodium). Light output is increased by a coating on the glass that is activated by electrical discharge. The type of coating determines the colour of the light emitted.

Efficacy: Rate at which a lamp can convert electrical power (Watts) into light (Lumens), expressed in terms of lumens per watt (Lm/W).

Electromagnetic ballast: A device that controls the starting voltage and operating current of a lamp. It uses a copper coil wound on a magnetic core.

Electronic ballast: A device that controls the starting voltage and operating current of a lamp. It uses solid state electronic circuitry. Electronic ballasts increase lamp efficacy, reduced ballast losses and are lighter and smaller ballasts compared to electromagnetic ballasts.

ESO: European Standardisation Organizations

ETSI: European Telecommunications Standards Institute

Fluorescent lamp: A high efficiency lamp using an electric discharge through low pressure mercury vapour to produce ultraviolet (UV) energy, which in turn produces visible light.

Glare: The discomfort or interference with visual perception upon viewing an extremely bright object against a dark background.

Halogen tungsten: Operation similar to incandescent tungsten except they use halogen gas in the lamp to prolong the lifetime of the tungsten filament.

High intensity discharge: A high efficiency lamp that sends an electrical discharge between two cathodes through a plasma, or ionised gas to produce visible light.

Illuminance (lx): The density of light (lumens/area) incident on a surface area. Illuminance is measured in lumens/m^2 or lux.

Incandescent tungsten filament: Lamp which emits light by heating a tungsten filament.

Kelvin: The unit of measure for colour temperature and is used to indicate the overall colour of the light produced from a source.

Kilowatt (kW): A measure of electrical power equal to 1000 watts.

Kilowatt Hour (kWh): The standard measure of electrical energy and the typical billing unit used by electrical utilities for electricity use. A 100-watt lamp operated for 10 hours consumes 1000 watt-hours (100 x 10) or 1 kilowatt-hour.

Light output ratio (LOR): The light output ratio of the luminaire, which means the ratio of the total light output of the luminaire understated practical conditions to that of the lamp or lamps contained in the luminaire under reference conditions. (SLL)

Lighting energy numeric indicator (LENI) (kWh/m2/annum): The actual energy consumption of a lighting system in kWh per square metre per annum. Sometimes referred to as power density. Specific formula used to calculate.

Lamp: A source that converts electricity into light.

Light emitting diode (LED): A small semiconductor device which emits light, usually coloured, when an electric current passes through it. LEDs have a long service life.

Lumens (lm): The basic unit of measurement for light. Luminous flux describes the total quantity of light emitted by a light source, both visible and non-visible. The unit of measurement is Lumens (lm).

Luminaire: Lamps and control gear are housed in fixtures called luminaires, alongside the housing, lamp holder and reflector.

Lux (lx): The SI (International System) unit of illumination: one lumen uniformly distributed over an area of one square metre.

Metal halide lamp: High intensity discharge (HID) gas discharge lamp that produces light by an electric arc through a gaseous mixture of vaporised mercury and metal halides.

Presence detection: A type of control which switches the lighting on when someone enters a space, and switches that off, or dims it down, after the space becomes unoccupied. (SLL)

REC: Registered Electrical Contractor

Re-strike time: The time period between switching a lamp on and it achieving full brightness from a 'hot start', i.e. the lamp has just been switched off.

SON high pressure sodium (HPS): SON is a high-pressure sodium-vapour lamp (also known as High Intensity Discharge, HID) similar to LPS lights but operate at a much higher lamp pressure. Can contain amounts of mercury inside the bulb. Commonly used for street lighting.

SOX low pressure sodium (LPS): SOX is a low-pressure sodium-vapour lamp with a specific type of gas-discharge light which produces a distinctive yellow light commonly used to light streets and roadways. They have very poor colour rendering.

Watt (W): A unit of electrical power. Lamps are rated in watts to indicate their power consumption. Power consumed over time equals the electrical energy used.

Sustainable Energy Authority of Ireland

Three Park Place,
Hatch St. Upper,
Dublin 2
Ireland

w www.seai.ie
e info@seai.ie
t +353 1 808 2100