GUIDE

LED Lighting Retrofit

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Should groups have any comments on this guidance they should email directors@communityenergy.london.

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1. Introduction

This guidance is for community energy groups looking to deliver an LED Lighting retrofit project. It should be read in conjunction with CEL's Step by Step Project Guide, which sets out the various stages to delivering a project from start to finish.

Groups are encouraged to read this guidance in full to understand some of the complexities of delivering a viable LED Lighting retrofit project. This guidance is not exhaustive but should give a good basis for projects, with information, tips, and tools that groups can use to help progress projects.

A directory of contractors, professional service providers and resources that groups have previously used can also be found on the CEL website to help groups when procuring various services.

The advantages of an LED Lighting retrofit project:

- LEDs are more energy efficient than other lamps/fittings.
- LEDs have a longer life, some can last up to 50,000 hours.
- LEDs will save site owners money on electricity bills and need to be replaced less often than other types of bulb.
- By replacing bulbs less often, you also reduce the quantity of material sent to landfill, and the quantity of raw material required to make the fittings.
- LEDs are a well established technology and relatively straightforward to install.

The disadvantages of an LED Lighting retrofit project:

- With LEDs, there are higher upfront capital costs, compared to other, more traditional bulbs.
- The quality of LED bulbs can vary.
- An overhaul of emergency lighting is required when switching to LEDs, which requires close attention.
- There can be complications with replacing lamps only (rather than whole fittings), as ballast should be bypassed in most cases.

LED retrofit projects are becoming an increasingly popular option for community energy groups, and there are a few different models a group can choose from to take forward:

- A standalone LED project involving a building-wide replacement of LEDs.
- LED lighting retrofit as part of a whole-building retrofit of energy efficiency measures, with the savings made from the installation of LEDs helping to finance other aspects.
- A group may take on the responsibility of the entire LED retrofit and pay for the install of the lamps or fittings themselves, through a community share offer or other means, or they may secure payment from the site owner. Alternatively, groups may opt to take a project management role, facilitating the LED project and receiving payment through an agreement on the energy bill savings made, a pay-as-you-save model, or a lighting services agreement
- Alternatively, a group might find a company to install LEDs, who agrees to be paid back through the savings which are likely to be guaranteed. With this option, groups should be wary of the rates of interest added on to the savings being paid back to the company, and should consider the bigger picture in how attractive this option is.

2. Suitable Sites

2.1 Optimum Conditions

A technically and financially viable site for a community LED retrofit project is likely to have:

- A large number of lights to replace - over 100 fittings at least.
- Lights used for long time periods - more than 8 hours a day.
- Common light fittings, not specialist lights such as theatre lighting.
- Fixtures and wiring in good condition.
- Average height ceilings, or only a small number of rooms with high ceilings.
- A high electricity tariff, above £0.20/kWh.
- An organisation that will be using the building for the next 10 years

2.2 Approaching a Site

Once you have found a suitable site, arrange to meet site owners/ managers to gather more detailed information about the site. Such as:

- Can you get a copy of the site's electricity bills?
- Are the buildings electrics and ceilings in good condition?
- Will you need to replace light fittings?
- Are there any obvious barriers to delivering the project?
- Can you complete a lighting audit, or work with a contractor to complete one?

LED lighting projects work well in buildings where light quality is particularly important, such as schools, universities and offices, however, groups should also consider opportunities in: leisure centres and gyms, community centres, care homes, warehouses, hotels, supermarkets and retailers.

Once you have found a site you will need to consider the required legal agreements for the project to go ahead. A key challenge includes the complexity and costs associated with putting in place such a legal agreement. Pure Leapfrog explains the various legal documents that might be required.

Site owners/ managers will need to set aside time for site meetings, lighting audits and visits. They should be made aware of this in advance and be happy to do so.

Additional Support:

- Contact your local council for an idea of what buildings might be suitable and attainable, and where they are already funding lighting upgrades so you can avoid working with these sites.
- Groups will sometimes have to make assumptions on a site's energy consumption when working out project feasibility, think about how the building is used at all times.
- The best way to see if a site is viable is to do a lighting audit. This is elaborated on in the next section
- You can ask a site's caretaker or site manager whether the site already has LED lighting, or the person who is responsible for fixing and replacing lights when they are faulty.

3. Feasibility

When finding a suitable site for LEDs, groups will also need to complete an initial feasibility study. This will involve conducting a comparison of costs, including running costs, to savings.

Once a site is found and secured, a full feasibility study will then need to be completed before securing capital funding. An independent lighting audit is a crucial part of this feasibility study.

Electrical testing tools, like clamp meters and energy loggers, can also help groups understand the energy consumption profile of a building. At times these can be costly or complicated to install, so are often used to monitor actual savings against expected savings, rather than to assess feasibility, or as part of innovation projects.

Consider all costs and potential income/ savings to determine if the project is economically viable.

Costs

This may include:

- Community consultation
- Energy audits/surveys
- Feasibility studies
- Project development
- Equipment and installation
- Access to lighting, such as scaffolding towers
- Making good (redecorating)
- Ongoing maintenance
- Running costs
- The cost of finance
- A contribution to any community fund (if applicable).

Dealing with electric wiring, fixtures, and circuits must be left to a qualified electrician, in accordance with building regulations. This will be at an additional cost.

Income

Estimate the potential electricity bill savings for each light replaced. Groups can also factor in savings on maintenance costs as a result of not having to change bulbs as often, if these are significant.

If at this stage the project looks unviable it must be stopped or re-designed.

3.1 Calculating Costs and Savings

LEDs in commercial buildings typically cost between £60 - £120, excluding VAT, including labour and materials.

Use the below equations to calculate energy, cost and carbon savings of switching to LEDs

Energy Consumption:

$$((light\ fitting/lamp\ wattage\ \times\ quantity\ \times burn\ hours\ per\ year) \div\ 1000)\ =\ kWh\ consumption$$

Calculate the energy consumption for both the old lighting (CFL/halogen/Incandescent) and the new LED lighting.) Calculate the difference between these two figures to find the energy savings.

Financial Savings:

$$((light\ fitting/lamp\ wattage\ \times\ quantity\ \times burn\ hours\ per\ year) \div\ 1000)\ \times electricity\ tariff\ £/kwh$$

Calculate the energy cost for both the old lighting (CFL/halogen/Incandescent) and the new LED lighting. Calculate the difference between these two figures to find the financial savings.

Carbon savings

Groups can convert savings (measured in kWh) into carbon savings by using the government's electricity grid carbon factor rate for any given year.

$$kWh\ consumption/1000\ x\ grid\ carbon\ factor\ t\ Co2e\ \ =\ tonnes\ carbon\ emissions\ equivalent$$

Calculate the carbon emission equivalents for both the old lighting (CFL/halogen/Incandescent) and the new LED lighting. Calculate the difference between these two figures to find the carbon savings.

CEL has more on calculating carbon savings in its Monitoring and Evaluation toolbox.

Additional support:

- CREW Energy, and SE24 and SELCE have a template financial model for LEDs. You can contact them via their website details, found on the CEL Member Groups webpage.

4. Operations and Maintenance

Groups may decide to take on the responsibility for the operations and maintenance of the LED lighting for a defined period of time, including replacing failed bulbs. Groups should hence keep a track of all costs and income following the install as well.

Ongoing maintenance may not be straightforward, as it may require a need for scaffolding to access certain lights. Groups/ site owners may choose to replace bulbs one at a time or in bulk which will also have an effect on costs.

Alternatively, groups or site owners may choose to put an LED Lighting Service Agreement in place with a company.

Groups may stipulate that they will provide maintenance for a grace period following install; for example, three months, which is usually sufficient to ensure there are no ongoing issues from installation.

Actual savings can be monitored and assessed against estimated savings, although the costs for installing monitoring equipment such as clamps on each lighting circuit may be high, and the technical feasibility of this will also vary between sites.

Additional support:

- CEL has developed a Monitoring and Evaluation toolbox to support groups
- SELCE and SE24 have template Lighting Service Agreements and financial models they would be happy to talk to other groups about. They can also provide training on lighting audits and access to auditing software. You can email ledlighting@selce.org.uk for more information.
- Wrike, Microsoft Tasks and Trello can all be useful tools for project management.
- Xero and Quickbooks can be used for accounting.
- CPDs from lighting manufacturers can be helpful to get a basic understanding of lighting technologies and solutions available, and are often free.

- The ECA or NICEIC websites can be used to find registered electrical contractors in your area.

5. Decommissioning

As and when lamps fail, it is best to recycle lamps or see if the manufacturer or retailer runs a take-back scheme. Recycling lamps ensures the valuable materials in old lamps can be reused. Confirm the lamp can be recycled by checking packaging.

Where recycling is not possible, confirm your local waste disposal advice for lamps. It is crucial to ensure that older bulbs, especially fluorescent tubes, are disposed of safely as these could leak toxic materials if smashed. Your installer should be familiar with the process of disposing of these safely, by using 'coffins' to return old lights to their wholesaler or manufacturer for recycling. Other materials such as ballast will ordinarily be sold to scrap metal collectors by your installer.

There is detailed guidance on the safe disposal and recycling of lighting and electrical equipment in the Waste Electrical and Electronic Equipment recycling (WEEE) regulations. You and your installer must abide by these regulations.

6. Lighting Technologies

Please note that lighting is a vast and in-depth area of electrical engineering. This section covers the basics of lighting, which are areas relevant for project managers and project officers to understand before undertaking a lighting project.

This guide caters for commercial and community buildings rather than domestic buildings. Light fittings may be similar in both settings at times, but the light technologies highlighted below are the most common in commercial buildings.

6.1 Incandescent Lighting

Incandescent light bulbs have been around over a hundred years, and are what people think of as the traditional or classic light bulb. This type of lamp produces light when an electric current passes through a filament wire, heating it to a high temperature until it glows.

The term Incandescence refers to an object emitting light due to its high temperature, and it differs from Luminescence, which refers to the emission of light by an object which is below the temperature required for incandescence.

Due to this method of light emission, incandescent light bulbs are highly inefficient, with only ~10% of the energy used being turned into visible light, the rest converted to heat. The luminous efficacy of an incandescent bulb is around 16 lm/W, compared to an LED lamp which is up to 70lm/W.

6.2 Halogen Lamps

Halogen lamps are a type of incandescent lamp using a tungsten filament, which are also filled with a small amount of halogen gas (e.g. iodine or bromine) in a capsule.

This combination of a tungsten filament and halogen case causes a reversible chemical reaction known as a Halogen Cycle to take place, this reaction causes the evaporated tungsten to form a Halide with the halogen gas. Once at a high enough temperature, the halide disassociates (breaks apart), which deposits tungsten back into the filament, thus extending the life of the lamp. This reaction also keeps the lamp clear - in an ordinary incandescent lamp, the filament is deposited on the inside of the glass bulb, reducing clarity.

6.3 Compact Fluorescent Lamps (CFLs) & Fluorescent Tubes

Compact Fluorescent Lamps are a low energy alternative to incandescent type lamps. These lamps consist of a glass tube filled with mercury vapour and gas, with an electrode at either end of the tube. When an electrical current passes through the gas, it excites the mercury vapour, which releases ultraviolet (UV) light. Because UV light is invisible to the human eye, a phosphor powder coating is applied to the inside of the glass tube. The UV photons interact with this phosphor coating, causing it to fluoresce. The colour temperature of the lamp can be varied by using different types of phosphor coating.

An electronic ballast is also required to limit the current in the circuit to prevent damage to the lamp. In the case of fluorescent tubes and most commercial type fluorescent lamps, the ballast is added external to the lamp, in the circuit or built into the fitting. For most compact fluorescent lamps, the ballast is built directly into the lamp in its base, allowing them to be used as direct replacements for classic incandescent lamps in the same fitting.

6.4 LED Lighting

LED Lighting is based on Light Emitting Diode (LED) technology, which results in lamps with significantly reduced energy consumption, but with lifespan and luminous efficacy several times better than that of both incandescent and CFL lamp types.

The Basics

LEDs use what is known as a semiconductor to produce light when an electric current is applied to it. It produces light because the electric current causes electrons within the semiconductor to move around, which releases energy in the form of photons (light). The colour of the light released is dependent on the material used as the semiconductor. Most semiconductors produce coloured light.

To produce the 'white' light that we use for domestic lighting, a mixture of colours or a phosphor coating (similar to CFLs) is used.

The Science

The main component of an LED is a 'chip' of semiconducting material. A semiconductor has the electrical conductivity between that of a conductor, such as copper wiring, and that of an insulator, such as rubber. This semiconductor is doped (intentionally introduced) with impurities, which modify the electrical properties of the semiconductor, in this case creating what is known as a p-n junction.

This p-n junction consists of a p-type (positively charged) side, and an n-type (negatively charged) side. The negative side has a high concentration of free electrons whereas the positive side has a high concentration of electron holes. Electron holes are the conceptual opposite to an electron, or the lack of an electron where one could exit.

When an electric current is introduced, electrons and holes flow into the junction, and when an electron meets a hole it releases energy in the form of a photon. The wavelength of the light emitted is reliant on the band gap of the semiconductor used.

The band gap is equivalent to the energy required to free an outer shell electron from its orbit about its current atom nucleus, to become a mobile charge carrier, and hence join with an electron hole.

7. How to choose LEDs

To determine what LEDs should be used, think about:

- Who are the users of the building?
- What are their needs now and in the future?
- Where is lighting needed?
- Are there architectural features you want to bring attention to?
- Do you want to create a mood?
- Do you want special lighting zones, for example if certain areas are used more than others?
- How are sensors used? How should they be used in future?
- What types of fittings exist (e.g. surface, recessed or pendant fittings)?
- What types of ceilings exist? For example, suspended ceilings, concrete ceilings, or high ceilings with wooden beams.
- Who will be replacing the lights in future and what is their preference?

7.1 Key Electrical Terms

Watts and Kilowatts

Watts (W) are a measurement of how much energy a lamp/luminaire uses. Traditionally, watts have been used to describe how much light output you would get from a lamp, however, this is becoming increasingly unreliable with newer, energy efficient technology. For example, with incandescent lighting a certain wattage bulb would indicate a fairly accurate light output range; however, with LED Lighting, a wattage does not necessarily guarantee a set light output. For this reason, contemporary lamps will be described using Lumens instead of Watts.

New energy labelling regulations now require the packaging to state the accurate Energy Consumption (EC) of the lamp, measured in kWh/1000h, if it differs from an already stated wattage. In the vast majority of cases, the EC will match the Wattage value. However, for any lamps with external ballasts or control gears, such as fluorescent tubes and 2D's, the EC will be slightly higher than the wattage. This regulation is important moving forwards as, where lamps are described in lumens, it is still important to know the energy consumption of the lamp.

Volts and Voltage

Voltage (V, Volts) is the term used to describe the 'force' of electricity within the electric circuit. The most common analogy for voltage is the electronic-hydraulic analogy, or drain pipe theory, which likens the voltage to water pressure inside pipes.

The voltage of mains electricity supply varies around the world. In the UK and Europe this is 220 - 240V, whereas the United States currently measures 120V. In terms of Lighting, the voltage of the lamp simply indicates the voltage at which the lamp is calibrated to function.

Lumens and Luminous Flux

In simple terms, the lumens (lm) can be thought of as the 'total amount' of visible light emitted from a source. For lighting, the higher the lumens value of the lamp, the more light it emits.

Lumens are also used to determine the Luminous Efficacy of a light source (how efficient it is at producing light), by calculating the Lumens per Watt (lm/W) for the lamp. The more Lumens the lamp produces per Watt of energy used, the more efficient it is at producing light.

Colour Temperature

Colour temperature is a standard method for describing colours for use in a range of situations. Colour temperatures are normally expressed in units called Kelvins (K). Note that the term “degrees Kelvin” is often used but is not technically correct. The colour temperature is for descriptive purposes only and does not relate to the actual temperature of the lamp.

7.2 Measurement of Light and Colour

Traditionally, the power of a lightbulb is measured in watts. However, the measurement of light is lumens. The higher the lumens, the brighter the LED bulb. In turn, the higher the lumens per watt, the more energy efficient the bulb is.

The colour of light is measured in degrees Kelvin (K).

- Daylight is 5,000k
- Cool white is 4,200k
- Warm white is 2,700k

‘Soft white’ or ‘warm white’ provides a cosy glow, best for homes.

‘Cool white’ or ‘pure white’ is ideal for offices and other areas that require clear vision.

There is also another colour measurement for LED bulbs, the colour rendering index (CRI). This measures the quality of a light source compared with sunlight. Sunlight is given the maximum CRI value of 100. The closer a lamp is to that, the better its ability to show true colours.

Some lights are also flicker-free which is a strong preference where building users are sensitive to flicker, such as people with disabilities such as autism, or ADHD.

Additionally, the fire safety rating of the light should be paid attention to. Any recessed fittings must have a TP (a) type plastic diffuser, which means they won't produce toxic gases when burned. Most lights now provide this as standard, but care should be taken to check this before ordering lights. Polycarbonate diffusers over 3mm thick are automatically classified as TP (a), along with any other thermoplastic material that self-extinguishes within 5 seconds when a flame has been removed. You can find out more about fire safety in lighting here.

Sourcing the right bulb can be challenging. Manufacturers will provide a specifications sheet with their lights so you can see all the details before you purchase them. You should also consult with the site to confirm they are happy with the lights you have chosen. You may wish to take advice from your installer, or an independent consultant, on the recommended replacement lights.

7.3 Swapping Like for Like

LEDs are 85% more efficient than halogens and 90% more efficient than incandescents. This table shows how bulbs compare at different wattages and brightness levels:

BRIGHTNESS IN LUMENS	220+	400+	700+	900+	1300+
STANDARD	25W	40W	60W	75W	100W
HALOGEN	18W	28W	42W	53W	70W
CFL	6W	9W	12W	15W	20W
LED	4W	6W	10W	13W	18W

7.4 Lumen Depreciation and Guarantees

The light of the LED will reduce over time. The L70 rating of a bulb tells you how many hours the bulb should give you an acceptable level of light intensity. An L70 of 50,000 hours is the current average rating for domestic LEDs. The better the L70 rating, the longer your LEDs will light to a safe standard according to current regulations.

Bulbs will come with guarantees, typically for 3-5 years. Consider purchasing higher quality bulbs with longer warranties for lights in hard to reach places.

It is important to carefully consider quality when purchasing bulbs. Better quality bulbs will last longer, provide a higher manufacturing standard, and perform as described.

7.5 Beam Angle and Shape

Beam angle and the shape of LEDs will also differ. The angle of light can be all around, a narrow beam or a spotlight for instance.

What you choose to install might be down to personal preference, what looks best aesthetically, or what is most suitable for the building or the bulb's purpose.

7.6 Light Fittings

LEDs tubes or lamps can fit into most existing light fittings, however, whilst this 'relamping' will cost less, it can affect the lifespan of fittings and/ or bulbs, or might draw more power from the LED causing it to flicker, especially where LEDs are used with dimmers.

Care should also be taken where ballast is used, and it is recommended that when retrofitted with LED tubes, ballast is bypassed. There are LED bulbs that may be ballast compatible, but the reliability of these varies and the tube compatibility must be checked with the specific ballast.

A more common option is to replace the whole fitting, rather than just a lamp or tube. This is because this is often more aesthetically pleasing, more reliable as there is no old technology being used in conjunction with new technologies, and because warranties on new fittings are generally longer than warranties on tubes or lamps only.

7.7 Controls

Bulbs can be turned on and off via a switch, sensor, timer, or be controlled using smart controls.

7.7.1 Smart Controls

LEDs with smart controls can be turned on and off remotely by an app or by voice. They can be controlled in groups and/ or by: timers, GPS, motion sensors, whether the building is in use, or the amount of daylight. These control systems can allow further savings to be achieved, however they will cost more initially. These are becoming common in the domestic sector, through technologies such as Google Home and Nest, Amazon Echo and Hive Smart Home.

7.7.2 Switches and Dimmers

The most common control is a standard switch, although often in rooms where mood lighting is required, such as auditoriums, or playrooms/nap rooms in schools, dimmable lights will be present. These lights are more expensive to retrofit, and care should be taken to replace dimmable CFL or other technologies with dimmable LEDs. If non-dimmable lamps/bulbs are used in a dimmable fitting, the light may flicker or malfunction.

7.7.3 Sensors

There are a range of sensors available on the market, but the most common are:

Motion Sensors

A motion sensor light triggers a response when motion is detected. They can be installed indoors, on walls, ceilings, and in doorways, or outside, on the exterior of buildings and homes.

Some kinds of motion sensor lights, called occupancy sensors, operate by turning off lights in unoccupied rooms and spaces. When motion is detected, the sensor triggers the light; when motion stops being detected, the sensor shuts off the light. Occupancy sensors are one low-maintenance method for cutting down on electricity bill charges from lights left on when no one is home or in a room.

Occupancy sensors can be controlled and adjusted to meet the user’s needs. Typically, two forms of motion sensor light control are offered: sensitivity and time delay.

A sensitivity setting enables the user to adjust the magnitude of motion that must occur to trigger the sensor. If properly set, a person walking in a room with a motion sensor trigger should activate the sensor, but a fly passing through shouldn't result in turning on the motion lights.

A time delay setting allows the user to determine how long the lights should remain on after the sensor is triggered if no further motion is detected. Motion light sensors can also be used in external applications, on the outside of homes and buildings, to sound an alarm or to turn on an outside light to announce a person's presence.

PIR Sensors

PIR (passive infrared) sensors utilise the detection of infrared that is radiated from all objects that emit heat. This type of emission is not visible to the human eye, but sensors that operate using infrared wavelengths can detect such activity. They are sometimes referred to as 'motion-based detectors', as they sense the presence of people, animals and objects through the movement of their infrared wavelengths.

They are referred to as "passive" due to the fact that no heat or energy is emitted by the sensor itself. These sensors are often used indoors in areas where the room occupants may be sat for a long time, such as classrooms, or offices.

The benefits are that they detect the presence of a person, rather than their motion, so they do not turn off the lights if a person has been sitting or not moving for a long time unlike motion sensors.

Photocell Sensors

Photocells are electronic devices you can use to manage indoor or outdoor lighting, but they are more commonly used in outdoor settings or indoors where areas have a large amount of natural daylight.

These sensors improve the security and safety of your home, automatically turning on lights when it gets dark. They also save energy by turning themselves off when extra light is unnecessary. They monitor the lux levels in an area, and will be triggered to turn on or off when a certain level of brightness is reached.

8. Case studies

Doddington and Rollo Community Association (DRCA), Battersea

All of the DRCA's rooms require continuous artificial lighting and, as a result, the Association had been suffering from high electricity bills, spending thousands of pounds each month. By installing LEDs, CREW Energy managed to save the DRCA £600-£700 per month - an 18% saving on their electricity bills. Furthermore, 116MWh, and 29 tonnes of CO_2 annually are also saved. The money saved goes towards repaying the loan to pay for the LEDs, and also into a community fund to support other projects.

Whittington Park Community Association (WPCA), North Islington

Power Up North London (PUNL) replaced all the existing lighting at the WPCA's centre with LEDs. The project delivered an annual electricity saving of 6.4MWh and delivered CO_2 emissions reduction of 3.5 tonnes per year. WPCA should also save at least £720 a year on electricity bills. As LED lights can last for years before they need replacing, WPCA will also benefit from a saving in the time and resources required to replace failed lights, many of which are very hard to access and take time for staff to replace.

9. Further resources

- Lighting guidance from the Church of England
- The CEL map shows all CE groups projects in London. LED projects can be found under energy efficiency.

10. Version control

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