Low Energy Lighting Guide for TV Productions

September 2011

BBC

ARUP

This Guide is intended to assist lighting directors, studio managers and production teams create low energy lighting designs and improve working practices in television productions

A low energy lighting solution is a combination of efficient equipment, efficient design, efficient controls and better energy management. This Guide will enable informed decisions to be made about the latest new lighting technologies that can enhance picture quality and creativity as well as improving programme operations.

Tungsten incandescent lighting has dominated the broadcasting world for more than 50 years. Now solid state lighting mainly from Light-Emitting Diodes (LEDs) is leading a new revolution in television production lighting.

Last year, the BBC carried out a quantitative energy analysis * on its production lighting over a representative set of TV studios. This analysis indicated that there is a potential to save between 30% and 50% of production energy lighting costs, as well as reducing CO_2 emissions. Savings can be made on energy use, cooling use and running costs by replacing existing incandescent production and house lighting with more efficient light sources and better design and improving energy management through sub-metering, training and working practices. The findings of this work were approved by the Carbon Trust and the results of tests carried out by the BBC Sustainability Team and Arup on the performance of the latest low energy lighting technology in operation in a studio environment are recorded here.

Solid-state lighting can now match - and in some cases exceed - the performance of tungsten with increased light output, better efficiency, good dimmability, high colour rendition and longer lamplife.

Low energy production lighting is happening now. Here at the BBC, lighting directors and programme teams will be using 100% low energy lights, mainly fluorescent, on the new set of the hospital drama Casualty when it moves to Wales. Studios in London and Salford will use the new LED fresnels for local regional news programmes, sports programmes, News Channel and on the new set of Breakfast. BBC Three's Mongrels has saved 40% of its energy consumption by using low energy lighting in their production, and Silent Witness is saving around 30%.

At the same time novel image capture processes such as High Definition and 3D television are setting new standards for lighting in TV studios. The BBC's R&D department have developed a pioneering new test to assess the colour rendition of low energy light sources for new camera technologies. No objective measure of lighting quality has existed before for the TV Industry.

This is an exciting time for the lighting industry and we are delighted to foster and embrace new technologies and techniques at the BBC, such as low energy lighting and Albert, the BBC's carbon calculator for productions. We intend to send clear signals to the broadcasting community and to its viewers about the leading role for the TV industry and our commitment to embed sustainability into every day programme making practices.

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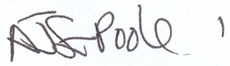

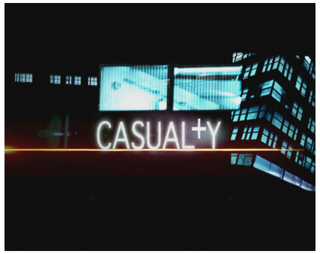

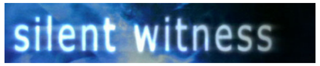

* http://www.bbc.co.uk/safety/default.aspxpage5530.shtml

Introduction

The BBC is excited to launch a unique "one-stop shop" Guide to Low Energy Lighting (LEL) for TV production. It is a comprehensive Guide on LEL, which will be useful for Lighting Directors, Studio Managers and Production Teams.

Up to 80% of the energy consumption in a production is from studio lighting. There are many advantages to be gained from using LEL – not least the reduction in energy consumption and carbon footprint. There are maintenance savings, as lamps last longer. There are more effective studio operations: for example, LEL can offer more flexible and dynamic ways to change light colour.

This Guide answers questions. What are the advantages and disadvantages of using low energy lighting equipment? How to introduce energy efficiency into your lighting design? How to manage your production to reduce its energy consumption?

The Guide is a useful resource for TV Lighting Directors. It outlines the latest thinking on the colour rendition as well as the impact of accessories on overall luminaire efficacy.

There is a useful matrix in section 4, which explains the various characteristics of LEL equipment.

Section 10 summarises actual measurement results – lux levels and colour rendition in a studio environment for currently available LEL equipment.

There are examples of TV productions which have switched to LEL, proving that it is possible to achieve a lighting solution that is wonderfully lit, cost effective and sustainable.

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Figure 1. Low Energy Lighting trial event in BBC Television Centre

1/ Sustainability at the BBC

The BBC's strategy "The Difference" sets the framework for our approach to environmental sustainability. We want to do all we can to reduce our impact on the environment from our buildings, technology, travel and programme making.

At the BBC we have a challenging target to reduce our energy consumption per person by 20%. Being more efficient with our energy use, and adopting low carbon technologies is crucial for us if we are to reduce energy consumption and CO_2 emissions. Low energy studio lighting can really help.

The Difference
sustainability starts here

albert
For sustainable TV production

Improving the quality and efficiency of lighting is a high impact sustainability improvement for any organisation. We think it is particularly important for the BBC in our studio and filming activities – we use a great deal of light, and it is highly visible too. The lights consume a lot of energy to power them, as well as to cool the surrounding space and this is where low energy lighting can make a real difference.

We are looking at other ways to make our productions more sustainable too.

Albert – the BBC/BAFTA Carbon Calculator

Albert is a BBC online tool which enables in-house programme teams to work out the carbon footprint of their show. It calculates the total amount of greenhouse gases (GHG) emitted into the atmosphere as a direct result of making the programme.

Users are asked to answer a series of questions relating to key areas of production: energy consumption in the office; studios and stages; edit suites; travel; overnight accommodation and power generators on location. The answers generate a series of user-friendly charts which show the user their footprint per series/episode and hour.

Use of Albert is mandatory within Vision Productions (the BBC's biggest programme-making division) and BBC Children's. Production Managers typically take responsibility for filling in the form and they and their Production Co-ordinators gather and enter data.

More than 150 footprints have been started in Albert over the past year, including a handful of radio productions. We now have a good understanding of what the average carbon footprint of an hour's worth of BBC-produced programming is, along with further detail on the average CO_2/production hour of certain production methods (location vs studio etc). These hourly averages can be further broken down into their carbon sources which will give us greater focus on areas of concern in the future.

The BBC is committed to sharing Albert with the rest of the industry and are doing so through a partnership with BAFTA. In the autumn Albert will move to the BAFTA website for use by any broadcaster or independent production company that wishes to do so.

The BBC plans to publish some of its production carbon footprinting data. We hope this will spark public interest and debate.

See page 12 for an example of a lighting energy calculation using Albert.

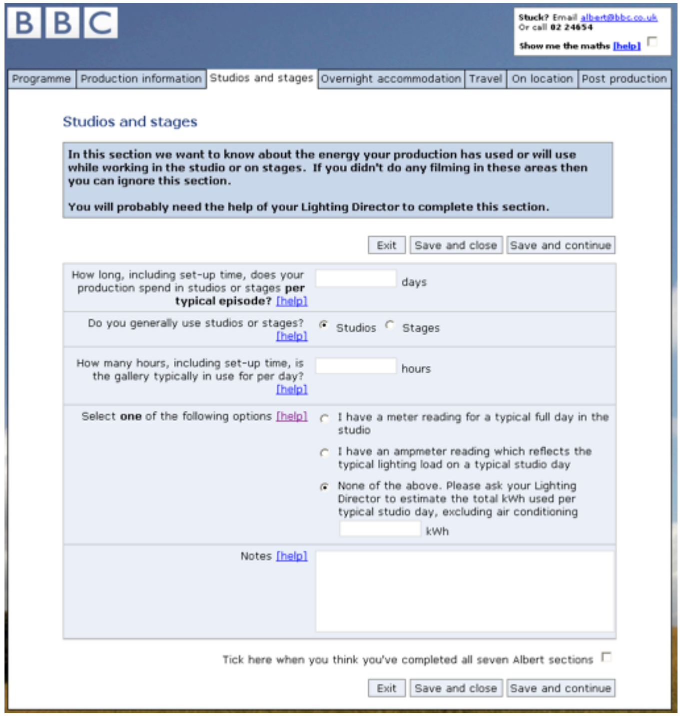


Figure 2. Lighting input required by *Albert*

2/ Low Energy Lighting Definition

For a TV production, a Low Energy Lighting (LEL) solution is the combination of:

- **Efficient lighting equipment** - light sources, luminaires (the optical system) and lighting controls,
- **Efficient lighting design** of the lighting installation,
- **Efficient lighting management** of the lighting equipment during all the phases of the production, including 'dark' practices.

If these conditions are met it is possible to achieve a lighting solution that is wonderfully lit, cost effective and sustainable. LEL should enhance the picture quality delivered, the creativity of designers and programme operations.

A LEL solution should match the performance of existing equipment (colour and lux levels), be easy to operate during filming, be simple to maintain and complement 3D and HiDef programme-making.

A LEL solution will reduce energy consumption, cooling requirements and reduce the frequency of lamp replacement. It is also important to *monitor energy consumption* to ensure that savings are measured.

However, an energy efficient lighting design does rely on having adequate choice, budget and time allocated to designers.

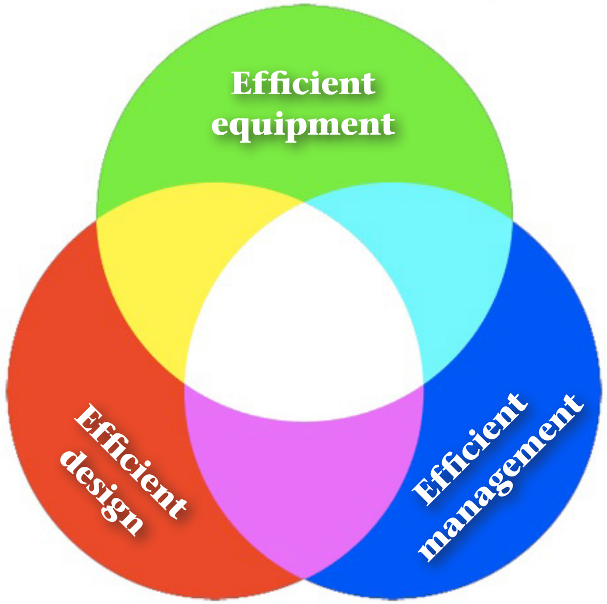


Figure 3. Holistic definition of low energy lighting

3/ Lighting Technologies for TV Productions

There are various parameters that should be taken into account when selecting TV production lighting equipment.

These can be grouped into two main selection criteria:

- **Performance criteria**: these relate to the physical characteristics of the lighting equipment and light source, such as:
  - power,
  - lumen output,
  - light source luminous efficacy,
  - luminaire light output ratio,
  - light source spectral emission, and
  - dimming curve.
- **Operational criteria**: these relate to the way the lighting equipment is operated and are not always easy to quantify. For TV production lighting applications these include:
  - adjustability,
  - yoke and pole operation,
  - shielding,
  - beam adjustability,
  - complexity of lighting control,
  - equipment maintenance, and
  - lamp replacement.

As lighting equipment is made of a number of technical parts – the *light source*, the *luminaire* and the *lighting control gear* – it is appropriate to treat them separately.

The following sections describe the latest lighting technologies used in TV productions. They outline the advantages and disadvantages of each type of light source. The **green** and **red** text highlight positive and negative performance, respectively.

Tungsten lighting

Tungsten incandescent and halogen lighting has dominated the broadcasting world for more than 50 years.

Tungsten lighting is very easy to understand because it is emitted by a thermal radiator that generates light by using an incandescent metal filament. By increasing the power and therefore the filament temperature, more light is generated, and viceversa by decreasing the power the light is dimmed.

As the filament temperature increases the spectrum of light shifts from the red heat of the filament to warm white light.

Characteristic features of tungsten lighting are **low colour temperature**, **smooth dimming**, **continuous light spectrum** and **excellent colour rendition**, **small size of light source** and **directionality of the light output**. Low voltage halogen sources require additional local transformers to operate, while mains voltage do not require additional equipment for switched operation.

Negative aspects of tungsten lighting are **low luminous efficacy** (between 10 and 20 lm/W, achieved with the more efficient HPL light source) **significant heat dissipation** (up to 95% of tungsten energy is dissipated as heat) and **short service life**.

Discharge metal vapour lighting

Discharge lighting is typically used in TV studios in "intelligent lighting" equipment and when it is necessary to provide higher lighting levels, for instance to simulate daylight.

For discharge lamps, the generation of light typically does not rely only on the temperature of the materials, but also on chemical or electrical processes.

Discharge light sources for TV studio lighting vary significantly. For television applications, it is possible to identify two main types of technologies:

- Metal halide lamps
- Hydrargyrum medium-arc iodide (HMI) lamps

Metal halide and especially *ceramic metal halide* lamps provide **high colour rendering**, **high brightness**, **high luminous efficacy** and **light directionality**. They have **long service life** (around 15,000 hours) and can have a **range of colour temperatures from warm to cool white**. **Dimming is typically achieved mechanically**. Metal halide lamps require electronic gear for their operation. They require an **ignition and warming time of several minutes** and a longer cooling-down phase before reigniting, but hot-restrike options are available for TV and film applications.

In television studios they can be used for key lighting applications with luminaire designs similar to those of tungsten lighting.

HMI lamps have been initially developed by OSRAM in the late 1960s after requests by German television producers to create less expensive replacements for incandescent lights. Philips produced a variation on the HMI, a single-ended version called MSR (medium source rare-earth) that with some variations is still in production. Several other lamp variations exist.

Within the last ten years, a lot of research has gone into making HMI bulbs smaller because of their use in moving light fixtures. Multi-kilowatt HMI lights are used in the motion picture industry and for large-screen slide projection because of their **daylight-balanced light output** (around 6000K colour temperature) as well as for their **high luminous efficacy**.

They generally have **low colour rendition** and don't dim, therefore **mechanical dimming is necessary**.

Similarly to most other mercury-based high intensity discharge lamps, HMIs **generate ultra-violet light**. Each HMI light must have a UV safety glass cover that should be used to protect talent in front of the light. Exposure to an unprotected lamp can cause retinal damage and severe skin burns.

HMI lamps can explode violently at the end of their **short lifetime** (around 1,000 hours). Therefore HMI lamps are typically not used past half their rated lifetime and their lamp-hours are monitored.

Fluorescent lighting

With fluorescent lamps, **the light is emitted from a large surface and is therefore diffuse**. For this reason, in TV studios linear fluorescent lighting is generally used for soft lighting applications. Compact fluorescent lighting does not have significant application in TV studios.

The light colours of fluorescent lamps are **warm white**, **neutral white** and **daylight white**. Fluorescent lamps feature a **high luminous efficacy** and **long lamp life**. Although the emitted spectrum is discontinuous, **special phosphor compositions can produce good colour rendition** at the cost of slightly reduced luminous efficacy.

Fluorescent lamps are low-pressure discharge lamps that work using mercury to emit ultraviolet (UV) radiation that is converted into visible light by fluorescent substances deposited on the inner surface. An inert gas fills the tube making the ignition easier and controlling the discharge.

Electronic control gear is necessary to operate fluorescent lamps. They ignite immediately and reach their full luminous output after a short interval (from a few seconds to a few minutes). An immediate reignition is possible if the current is interrupted. Fluorescent lamps **can be dimmed smoothly** depending on the control gear and specialised flicker free dimming ballasts have been developed for motion picture applications. However, for TV applications, **dimming to less than half the lumen output produces a visible colour shift**.

Tungsten lighting has not been the only privileged type of lighting source within the motion picture industry.

At the beginning of the 20th century, the constraints imposed by the sensitivity of the early filming equipment demanded a higher light output that could only be provided by carbon arc lamps. The introduction of panchromatic film and sound, the advent of colour photography and the Technicolor process have all played a significant role in establishing the success of tungsten lighting within the entertainment and motion picture industry.

Tungsten lighting allowed artistic freedom and lighting control and gradually replaced carbon-arc lighting during the first half of the 20th century.

Similarly, solid-state lighting is now leading a new revolution in TV production lighting.

Solid-state light emitting plasma

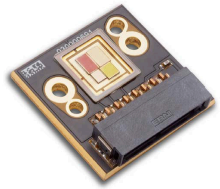
Light Emitting Plasma (LEP) include a solid-state device that generates radio frequency (RF) energy to power a plasma light source. They contain a very small amount of mercury compared with typical high-intensity discharge (HID) sources of equivalent power.

LEP sources are patented and manufactured only by the LUXIM company. They combine the **long service life** of solid-state lighting with the **high brightness** of HID sources.

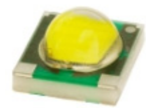
Their **colour temperature is 5300K**.

LEP sources come up to full power typically within 30 to 60 seconds of turning them on and can re-strike within 60 seconds.

LEP lamps feature **high luminous efficacy** (up to 115 lm/W), **continuous light spectrum**, **high lumen output**, **good colour rendition** and **directional light output** due to the small light source size. The manufacturer claims the **ability to dim smoothly to 20%**, but **while dimming, the spectrum of light moves towards the blue end, lowering the colour rendering and increasing the correlated colour temperature**. For TV lighting, smooth dimming to 0% can only be achieved mechanically depending on luminaire design, similarly to discharge technologies.







Solid-state LED lighting

Light emitting diodes (LEDs) are electroluminescent semiconductor sources. Light is generated by recombining charges in a semiconductor with an appropriate energy band gap.

Standard LEDs produce narrow-band radiation that appears to the human eye as saturated colour. For this reason initial LED applications have focused on *coloured light*. Coloured LEDs offer the **advantage of emitting coloured light very efficiently** if compared to using subtractive and dichroic filters with other light sources.

White light cannot be produced directly with semiconductor materials. Currently, LEDs can generate white light using two indirect methods:

- RGB mixing,
- Luminescence conversion.

RGB LEDs combine three coloured light diodes emitting red, green and blue light (RGB). The light colours can be mixed to produce a wide range of colours, including white, by adjusting their different light intensities. **The colour rendering of white light generated with RGB LEDs is generally poor**. But by using a higher number of coloured LEDs **it is possible to shape the spectral emission to create a continuous spectrum offering high colour rendering**. However this approach generally makes the light source dimensions bigger, with adverse effects on beam control.

LEDs producing white light with *luminescence conversion* typically convert the spectrum of coloured LEDs by using phosphors as a luminous layer. Currently, the preferred approach to produce white LEDs is to use blue LEDs with yellow phosphors coatings.

With this technology, it is possible to obtain better spectral distributions and **good colour rendering**, approximating R_a 90. The white light colours available include **warm white**, **neutral white**, and **daylight white** with colour temperatures between 2500K and 8000K.

LEDs can be extremely different in terms of colour characteristics, but also in their type of construction and form factor. The following LED shapes are used:

- *T-type LEDs* - They have a plastic housing with a diameter of 3-5mm for the wired LED. The shape of the lens determines the light emission angle. They tend to have low luminous flux, but some TV lighting manufacturers have used them in large arrays for soft lighting applications.
- *SMD LEDs* - The “Surface Mounted Device“ (SMD) LEDs have soldered contacts and light emitting components glued directly to the circuit board.
- *COB LEDs* - “Chip on Board“ (COB) LEDs have a protected sealed chip placed directly on a circuit board without its own housing.

High power SMD and COB LEDs have power consumption above 1W. In these LEDs, thermal management is a key factor because light is generated in a very small surface and their construction has very low thermal resistance between the chip and the circuit board. For this reason high-power LEDs are usually used over metal core circuit boards that **require special thermal management in the luminaire**. The output of the LED decreases with increasing temperature. Consequently, good heat dissipation is important for smooth operation.

Some LED fixtures are actively cooled with fans; this can cause problems in studios as they may generate noise.

LEDs used for lighting **do not produce UV or IR radiation**, but generally **contain more blue light than other sources** and this can make use of some filters problematic.

They are characterised by **compact shape** and **small form factor**, **extremely long service life** (50,000 hours according to manufacturers) and **high impact resistance**. For these reasons they are less likely to fail at a critical moment and need less maintenance.

They have **low energy consumption**; therefore their **luminous efficacy is high** (40 - 80 lm/W currently) and has been steadily increasing during the past few years.

When dimmed, the **colour temperature remains constant as the light intensity decreases**. This can be positive or negative depending on the lighting application, but lamps including both white and RGB LEDs can mimic the behaviour of the colour shift created by tungsten dimming.

LEDs need **electronic control gear to keep the correct operating current constant**. They **start instantly - no warm-up time** - and **react quickly to dimming and control**.

Colour consistency and the reduction of production related colour deviations for LEDs is a particular challenge for manufacturers. They sort LEDs by luminous flux and dominant wavelength and give them a bin code and a rating. This sorting of LEDs is called binning and can be more or less precise depending on the manufacturer. MacAdam ellipses (see page 23) are extremely useful to understand the colour variance of LEDs within a certain luminaire model.

4/ Luminaires and optical systems

Luminaires for TV lighting have extremely varied designs and perform a wide range of functions.

The most important task of a luminaire is to direct the lamp's luminous flux in a controlled way in the right direction. The objective is to **distribute light in a way that best suits the particular task and creative idea, while making the best possible use of energy**.

In addition to design-related aspects of luminaires as specialist lighting devices, those aspects relating to installation, aiming, remote operation and safety are also relevant.

Luminaires direct light using an **optical system** generally composed of **reflectors and lenses**. The beam can also be shaped outside the luminaire body using accessories such as *barn doors*, *honeycombs*, *egg-crates*, *framing attachments* and *gobos*. The spectral composition and perceived colour of the light can be changed with *filters*.

All these reflectors, lenses and accessories reflect, transmit and absorb light, therefore reducing the initial lamp luminous output. For this reason it is important to introduce the concept of **luminaire light output ratio (LOR)**. This is the ratio between the lumen output from the luminaire and the lumen output from the lamp itself.

Even if efficient light sources are used, a **low LOR lantern can have a very negative impact on the efficiency of a lighting design**.

It is therefore recommended to investigate the luminaire optical performance in order to assess the light output ratio and verify the total emitted lighting flux rather than only that of the light source. In fact, tungsten sources with efficient and precise optical systems can be more efficient than other lighting instruments including low energy light sources under certain circumstances.

Fresnels, plano-convexes (PCs) and profiles are able to shape, focus and direct the lighting beam depending on the relative distance between the optical elements. This has a direct influence on the distance where a suitable lighting level is reached (**beam throw**) and on the diameter of the lighting cone (**beam aperture / beam angle**).

The most common types of stage lanterns are shown diagrammatically in Figure 5.

Some low energy lighting sources have stimulated new luminaire designs. This is particularly true for LED luminaires, because of the nature and shape of this novel type of light source. Modular LED arrays (see Figure 4) are an example of a new lighting concept that requires a change in lighting design and working practice.

Figure 4. New LED luminaires designs

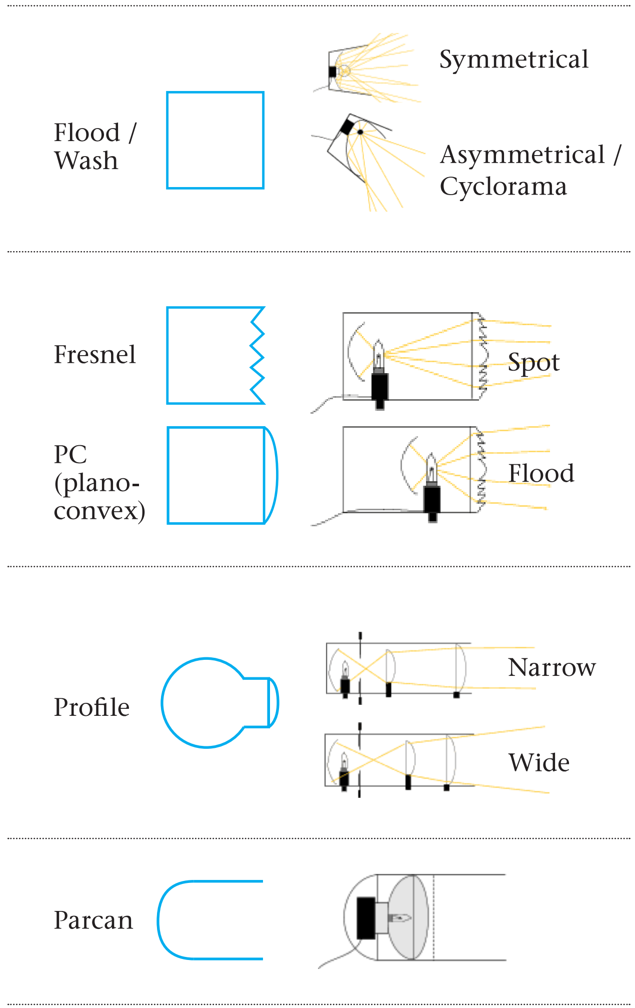


Figure 5. Main types of reflector and lensed TV and stage lanterns

Performance Criteria for TV lighting

The matrix presents the main performance criteria for different TV Production Lighting technologies.

A simple "traffic light" colour system has been used to show the results and highlight which technology performs better on each one of the performance and operational parameters.

It is apparent that cost is the main barrier to the implementation of low energy technologies such as LEP and LEDs.

	Dimming	Colour rendering	Beam throw	Beam control	Warm-up time	Lamp life	Energy consumption	Luminous efficacy including optics	Cost	Appropriate applications
Tungsten Incandescent			more energy required for bigger distances		no warm-up time	~100 - 1,000 hours	luminous efficacy is too low	~ 10 lm/W		key lighting
Tungsten Halogen with good optical design / HPL			more energy required for bigger distances		no warm-up time	~ 100 - 2,000 hours	possible to switch on instantly, good for energy management	~ 20 - 30 lm/W		key lighting
Discharge CDM	mechanical dimming	good with ceramic metal halide lamps	excellent with big distances	good, but mechanical dimming can interfere	~ 1 - 5 minutes	~ 500 - 15,000 hours	dimming and warm-up time have a bad implication on energy management	~ 50 - 90 lm/W		key lighting moving lights
Discharge short-arc HMI/MSR	mechanical dimming	variable, depending on lamp type			~ 1 - 5 minutes	~ 400 hours	dimming and warm-up time have a bad implication on energy management	~ 50 - 80 lm/W		key lighting follow spot moving lights
Discharge plasma	only down to 20% but with colour shift, then mechanical dimming				~ 1 minute	~ 10,000 hours		~ 50 - 80 lm/W	cost is still high but could decrease with more widespread use	key lighting moving lights follow spot
White LED matrix	potentially good, but some unreliability at bottom of the scale	spectral distribution has local peaks	highly depends on optical design ad LED source	variable, depending on optical design	no warm-up time	~ 25,000 hours		~ 40 - 60 lm/W	cost is still high but could decrease with more widespread use	key lighting soft lighting
White LED chip	potentially good, but some unreliability at bottom of the scale	phosphor LEDs can provide continuous spectrum	highly depends on optical design and LED source, bigger sources for higher outputs	smaller sources provide better control / lenses	no warm-up time	~ 25,000 hours		~ 40 - 70 lm/W	cost is still high but could decrease with more widespread use	key lighting
Colour LEDs		not applicable	saturated colour can reach high intensity	lenses	no warm-up time	~ 25,000 hours		direct emission of saturated colours	cost is still high but could decrease with more widespread use	cyclorama effects set dressing
Fluorescent	only if specialist control gear used	possible to achieve Ra>90 with special lamps	difficult to achieve big distances, more lamps required, large luminaires	large source	~ 1 - 5 minutes	~ 8,000 - 20,000 hours		~ 70 - 100 lm/W		soft lighting cyclorama

Figure 6. Lighting technology performance criteria comparative matrix

5/ Energy Monitoring

It is important to measure the energy consumption of a TV production. This will allow users to understand how the production is designed, controlled and managed.

Metering tools will enable production usage patterns to be understood. It will assist with identifying wastage and ensure long term energy management for each production. Smart metering, can help with the analysis of peak loads and see trends and improvements.

This information can assist the purchasing decision process and give a direction to the Lighting Director about how to improve the next design and specification.

Energy calculation using the BBC carbon calculator

Installation of energy monitoring equipment is recommended in order to provide accurate energy data for the lighting section of *Albert*, the BBC online tool which allows users to estimate the carbon footprint of TV productions.

Albert asks users to enter a figure relating to the typical daily energy consumption of lighting in the studio or stage. Inputting an ampmeter reading is not reliable in many cases, since lighting shows are typically very dynamic. Ideally this number should come from a sub-meter or similar, but where none is available the user is asked to enter an estimate, which the Lighting Director may be best placed to provide.

Albert automatically doubles the kWh figure entered to take cooling into account if the production is studio-based. It doesn't do so if the production is based on a stage as typically these areas do not use air conditioning

A simplified calculation to derive the daily kWh is shown below. The typical cumulative daily energy from a single luminaire is given for each luminaire by the following formula:

daily energy [Wh] =

power [W] x *hours run* [h] x *electrical dimming factor*

The power of the luminaire in watts (W) must include the additional ballast power, and not only the lamp rated power.

Unless the luminaires are fitted with individual lamp-hour monitoring, the quantification of the hours run can be difficult and only be left to the informed judgement of the Lighting Director.

The electrical dimming factor is a number that expresses the portion of power required by the luminaire when dimmed. This is a difficult number to obtain, as different lighting technologies and products have different dimming curves that are not easily provided by manufacturers. For this reason it can only be expressed as an estimate. For example, discharge luminaires that dim mechanically will always have a dimming factor of 1, while dimmed tungsten, LED and fluorescent luminares will have factors lower than 1, according to the power drawn after dimming. This can be measured for better accuracy, or estimated within a certain percentage of error.

The sum of this number for each luminaire provides the final cumulative daily energy consumption from lighting in Wh. Dividing this number by 1,000 gives the result in kWh.

It can be practical to use a table or a spreadsheet to calculate this number, as shown in the example below.

Luminaire	Luminaire power (W)		Total installed power (W)	Hours run	Dimming factor	Energy (Wh)	Energy (kWh)
Dual source (tungsten)	**1,250**	**5**	**6,250**	**2**	**0.5**	**6,250**	**6.250**
Source four (tungsten halogen)	**575**	**5**	**2,875**	**3**	**0.2**	**1,725**	**1.725**
Canara CC280 (fluorescent)	**160**	**3**	**480**	**4**	**1**	**1,920**	**1.920**
Kezia 200 (LED)	**190**	**3**	**570**	**4**	**1**	**2,280**	**2.280**
TOTAL		**16**	**10,175**			**12,175**	**12.175**

Figure 7. Example of a cumulative energy calculation

Lighting control and studio management

Working efficiently with lighting equipment means avoiding unnecessary use of energy.

Maintaining the efficiency of lighting equipment is achieved by ensuring that clean equipment with clean optics is used. Switching off lighting when not in use is also important.

It has become common practice to leave discharge moving lights on during set preparation and rehearsal (see energy plot for a day of entertainment lighting in Figure 8 - above). In some cases this means they come on at the start of the day and stay on all day, even if they are only used for two hours of performance in the evening. This practice probably dates from the early days of moving lights, when they were less reliable than they are now and it was felt that the lamps were failing more often from being repeatedly turned on and off than for running for long periods.

This is not the case with modern equipment and light sources. Today, manufacturers recommend turning the discharge lamps off when not likely to be in use for at least one hour.

Another problem is when staff are not trained on how to use the studio space and don't take ownership of it. The energy plot in Figure 8 (below) showing a week of drama shooting emphasises this, highlighting that the ~~warehouse~~ house lighting has been left on every day, even when the facility was closed.

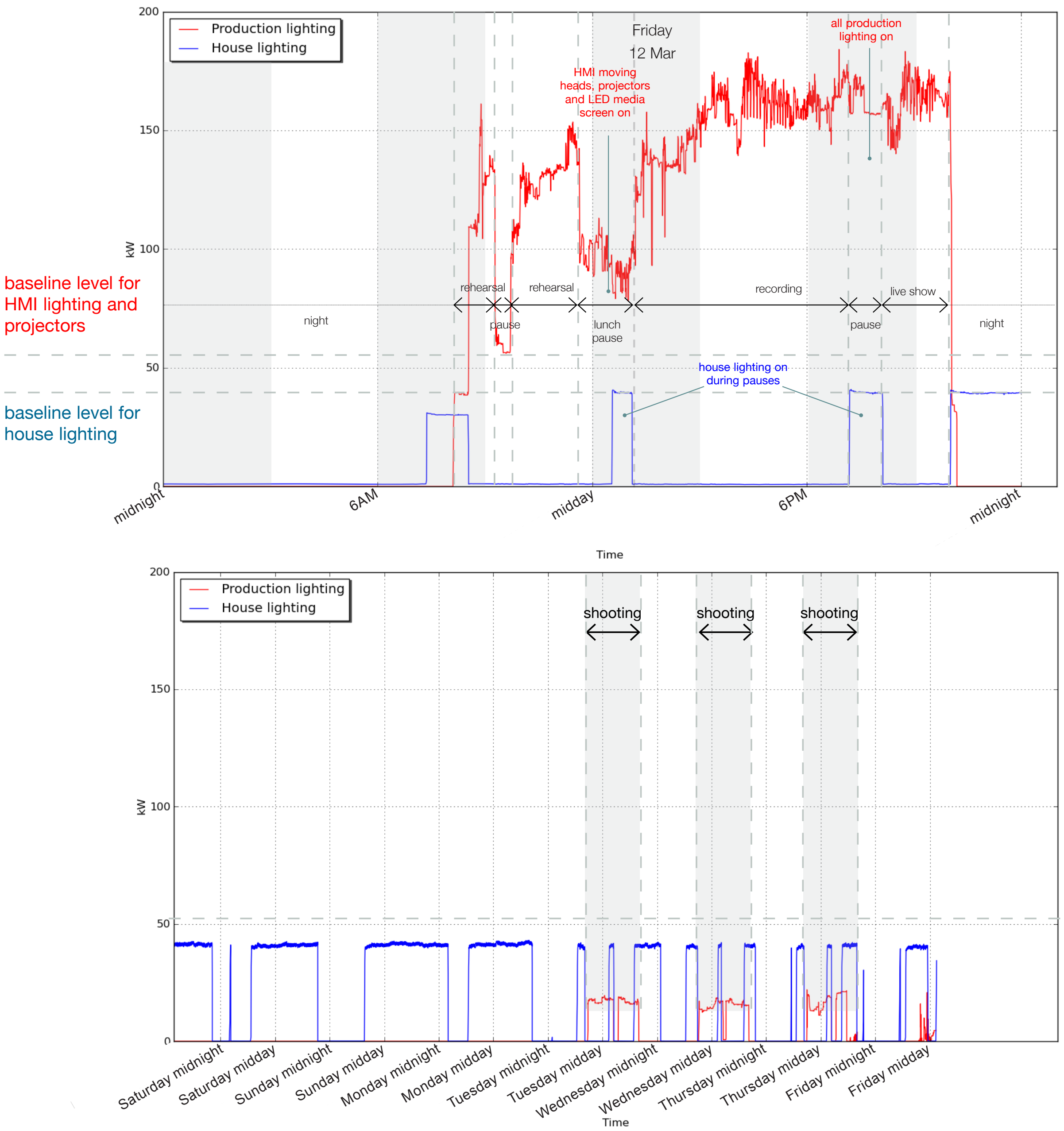


Figure 8. Energy profiles for a day of entertainment show (above) and a week of drama episodes shooting (below)

6/ Procurement

The initial capital cost of low energy lighting equipment is the biggest barrier to successful implementation of low energy lighting in TV studios. Whole-life cycle costs, maintenance costs and replacement costs need to be considered. There are also significant savings on air conditioning cooling costs.

The largest environmental impact of most products, are from its manufacture and its disposal. It is therefore sensible to only purchase what is needed and use the equipment for as long as possible. There is also an environmental carbon footprint associated with the transport of hired lighting equipment. There is a reduced environmental impact if equipment is purchased and stored near the studio or production.

The hiring costs, energy costs and lamp replacement costs can be used to calculate the number of days after which hiring has paid the entire capital cost of each luminaire. The period can be as low as approximately 3 months for tungsten equipment, but for low energy lighting the payback period is around 6 months, with the most expensive LED moving head luminaires being paid back in just over one year (see figure 9).

Special consideration should be given to the environmental policies of the chosen suppliers, with preference given to those who can prove their commitment to sustainable practice.

The British Standard 8903:2010 "*Principles and framework for procuring sustainably – Guide*" gives recommendations and guidance on how to embed sustainable procurement practices across organizations and their supply chains. It is recommended to refer to it to assess the extent and effectiveness of the aspects of sustainable lighting procurement for TV productions.

The British Standard 8901:2009 "*Specification for a sustainability management system for events*" outlines the requirements of a management system to improve the sustainability of events and can also be used to inform and implement a sustainable lighting procurement process.

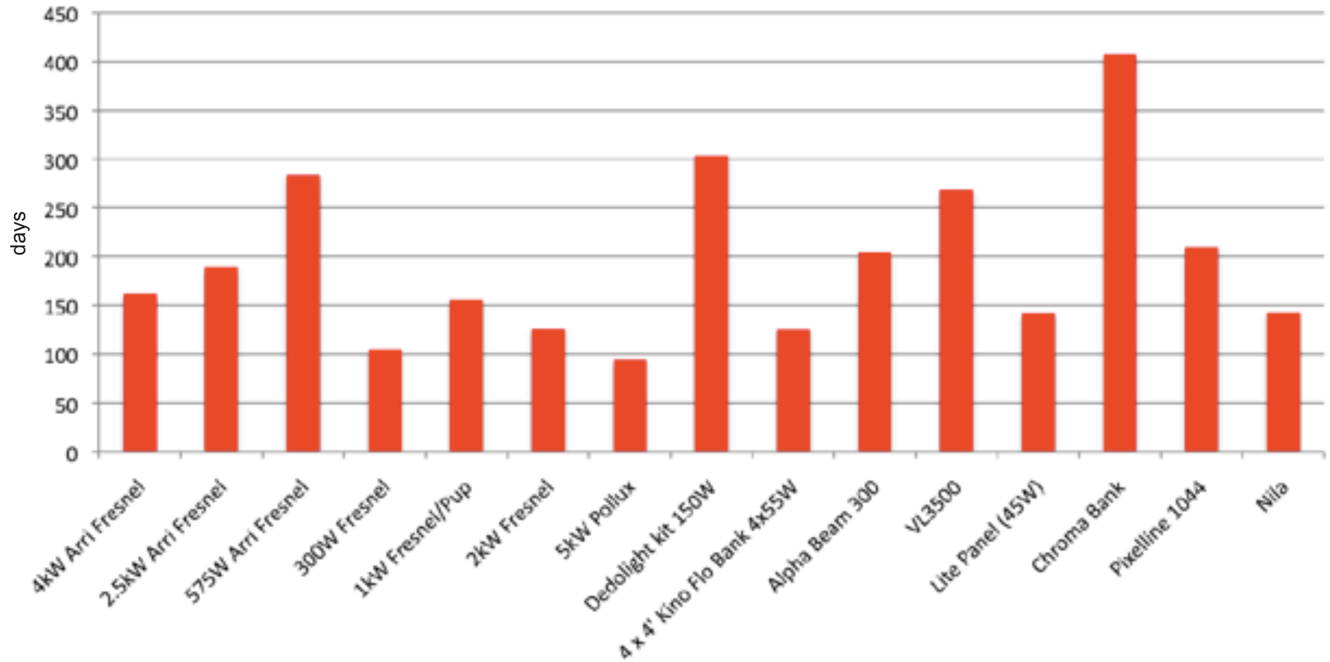


Figure 9. Expected payback time in days for a range of hired studio lighting equipment

7/ Health & Safety

Low energy lighting sources have emission spectra that can appear similar in colour temperature but whose composition can have higher power in narrow areas of the spectrum.

A two year industry project carried out by the Professional Lighting And Sound Association (PLASA) and the Health Protection Agency (HPA) has looked at how entertainment lighting typically performs against the Artificial Optical Radiation (AOR) Directive. The results tell us we can assume that entertainment lighting equipment is safe in terms of AOR exposure unless:

- UV is inadequately filtered and / or
- Illuminance is greater than 1000 lux over 8 hours and/ or
- We have specific information (eg. from the manufacturer due to a previous incident) to tell us that a particular light may be unsafe.

BBC Safety advises that the hazards should be assessed and controls put in place for any activity which results in the emission of artificial radiation in the optical wavelengths which includes Ultra Violet (UV) and near Infra Red (IR) radiation.

If UV radiation is suspected then it is advised to use a device such as a UV sensitive patch or a digital UV meter to confirm the presence of UV. If UV radiation is present, then it is necessary to eliminate or measure to prove that over-exposure cannot occur.

If UV radiation cannot be eliminated by turning off the light or using an alternative light source, then it is advised to use a UV filtering gel. A UV filtering gel must always be fitted to any HMI light. When using portable HMI lights, a UV filtering gel must be used unless it has been proved that there is no UV radiation emitted.

It is recommended to turn off lights when not needed.

IR radiation can cause heating effects – including thermal burns, but normal aversion responses to very bright light make it very unlikely to be a significant issue.

LEDs do not emit UV and IR radiation, but similar to daylight balanced sources, they have a higher content of blue light. Blue light is an important element in ‘natural’ lighting.

The HPA indicates that blue light might be a problem if a bright light is viewed directly for an extended period as blue light does not trigger an aversion response. Their measurements indicate that production lights can be looked at safely for up to 8 hours where the illuminance is 1000 lux, 4 hours where the illuminance is 2000 lux, 2 hours where the illuminance is 4000 lux and so on. As production lights typically emit energy in other wavelengths as well as blue light, the aversion response is considered to provide protection. It is not necessary to consider the cumulative risk from more than one light source except for UV radiation. This is because typically it is not possible to view more than one light source for extended periods. There is a known risk of excessive UV emission from some HMI lights. Lamps that are further away than 5 metres (for example in studio grids) are unlikely to be a hazard because the intensity of the UV radiation falls off rapidly with distance.

UV emission measurement test reports for photobiological safety according to IEC 62471 will review the risk for groups of UVA, actinic UV and blue light hazard. Risk group 0, means ‘no risk’, risk group 1 ‘low risk’ and risk group 2 ‘moderate risk’. The Blue light function is defined only in the visible wavelength range, 400 to 500 nm. By filtering away the main part of the blue light the CCT, CRI, illuminance and/or luminance may be sacrificed. There may not be a practical chance for reaching Risk group 0 for some professional lighting systems.

8/ Low Energy Lighting Design Notes

> *It is all too easy to confuse effects*
> *with effective lighting,*
> *startling images with unforgettable ones,*
> *quantity of footcandles with quality of light*

Ross Lowell, *"Matters of Light and Depth"*

The UK has a commitment to reduce its Carbon Dioxide (CO_2) emissions.

The BBC is committed to making its programmes in a way which will have the minimum impact on the planet and the maximum benefit to the people and places involved in their creation.

We're not alone in this aim. Industries across the world are doing the same thing and some big names in the broadcasting field – including major players in Hollywood – want to ensure their work is socially beneficial and not environmentally damaging and wasteful.

The aim is to help make your programmes to the same high standard as always but with the minimum negative impact on current and future generations.

Depending on the type of fuel used for power generation, **energy consumption** has an impact on the emission of greenhouse gases (GHG) of which carbon dioxide (CO_2) directly impacts on the environment. If the energy used was from renewable sources we could solve nearly all of the environmental issues. Governments have taken some important steps towards facilitating the production of renewable energy, but this is still less than 1% of the energy generated in the UK.

Lighting is a key area to save energy for a production. Typically, 80% of the energy costs in a studio or production space will be lighting related.

But energy consumption is only one part of the equation: whole-life, maintenance and replacement costs also need to be considered. The environmental impacts should be considered at each stage too.

Energy is needed to manufacture the lighting equipment – this is known as the **embodied energy**; from sourcing and processing the raw materials, transporting the finished products and disposing of them at the end of their life. Lighting products can also create **pollution at the end of** their **life cycle**.

For TV lighting, this means rethinking the overall process, from planning the lighting design, procuring the equipment, running the show (rigging, running, de-rig), dismantling, maintaining and disposing of equipment at the end of it. It is important to involve lighting directors, studio managers and production teams at the planning stage to ensure that the optimal solution is found.

Each type of low energy lighting source has a distinct character and this, coupled with different luminaire designs, can generate frustration if approached from the design mind-set connected to conventional tungsten lighting equipment. Much more can be done than replacing like-for-like luminaires. There are opportunities presented by new lighting technologies.

There is a wide range of things that can be done to improve efficiency. It is important to remember that an integrated lighting solution is much more efficient than individual efficient light sources.

The next sections offer some suggestions to make TV lighting more efficient.

House Lighting

House lighting and worklights, especially in old studios, can be a significant electricity consumer. This is especially true when a tungsten floodlighting system is in place and little attention is paid to turning it off when not needed.

It is recommended to replace tungsten and older discharge and fluorescent house lighting with dimmable T5 fluorescent lighting. This can achieve more than 50% savings for each luminaire, with an average payback of 3 years. Attention must be paid to the lighting control system, as in some studios smooth dimming of house lighting can be important.

Introduction of lighting controls, such as absence detection and time control in storage rooms, dimming rooms and other technical spaces, can save energy. Surveys have shown that these auxiliary spaces are often left lit when unoccupied.

If there are no lighting controls, staff should be trained to take ownership of the lighting management of these spaces. Energy saving strategies such as turning off lighting at night and when the space is not used, and dimming lights during certain periods, should be implemented.

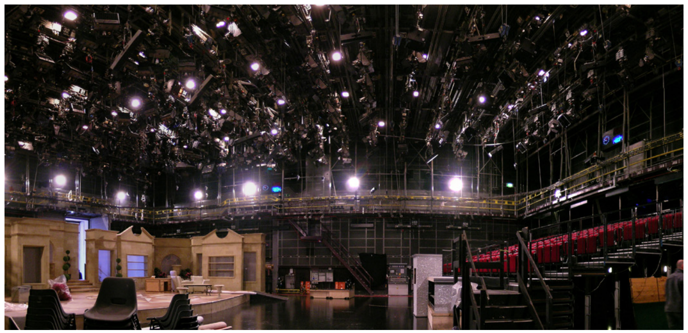


Figure 10. Tungsten house lighting in the TC4 studio

Performance lighting

The choice of the replacement products cannot be taken considering only energy efficiency: light spectrum and colour rendition, colour temperature, dimming, beam control, beam throw and availability of accessories for studio lighting are among the criteria that play an important role and must be considered when selecting a particular lighting instrument for a TV studio. At the same time the creative style of the lighting director can privilege a particular type of luminaire.

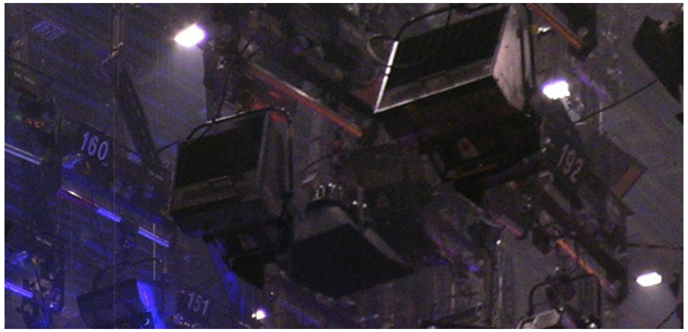


Figure 11. Dual sources

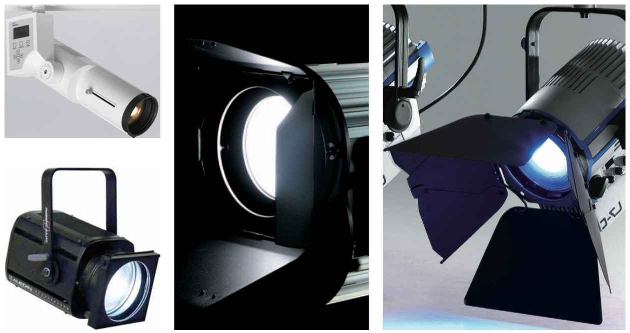


Figure 12. Examples of LED hard-lights

Hard-lights

Hard lights are directional and are usually created with lensed lighting instruments having small, compact light sources. They are typically used for key, fill and backlighting.

In TV studios, tungsten 1kW, 2kW or dual-source switchable power lanterns are typically provided and mounted on pantographs. Dual-source luminaires are designed to reduce rigging time and offer flexibility to lighting directors, including a fresnel lens and barndoors on one side and a “soft” end on the other. They are extremely versatile luminaires with a long service life that are difficult to replace with low energy alternatives because staff are very accustomed to them.

However, lower energy alternatives already exist and should be considered in future productions:

- Efficient lensed lanterns using tungsten halogens having better performance have been on the market already for a long time.
- New lighting instruments making use of white, tunable white and colour LEDs for short beam throws (up to 5 m) and plasma sources for long beam throws (5 m and above) are already available.

Discharge luminaires, using light sources with good colour rendering, can also offer an efficient studio lighting solution, despite their lack of electrical dimming. Discharge lighting is 5 to 8 times more efficient than conventional tungsten studio lighting. This means that, even if discharge lights can only dim mechanically, they need to be on 5 to 8 times longer than tungsten lights to balance out the power consumption.

Soft-lights

This is an area where low energy lighting can bring better efficiency with little change and significant operational improvements.

Soft-lights are lights designed to illuminate diffusely and create soft-edged shadows and highlights. It is a broad category of lighting instruments that can also include tungsten “hard-lights” illuminating through a large piece of diffusion material or using a large white matte secondary reflector. These methods are very inefficient ways of diffusing light: the diffusion material in a fabric softbank or the matt white reflector typically absorb more than half the light, reducing even more the efficiency of low lumen output luminaires.

LED and fluorescent softlights today offer compact design and the best performance. They can save at least 75% of the energy consumed by tungsten softlights with comparable effects.

When using softlights it is important to take into account the relative and interrelated effect between the emitting surface size and the distance to the subject. Because of their design, open faced LED matrix softlights can show multiple shadows and highlights if the distance is approximately less than 5-10 times the emitting surface bigger dimension, depending on the LED pitch. With careful design these visual artefacts can be avoided.

Figure 13. Examples of LED soft-lights

Cyclorama and wash-lights

Fluorescent and LED lighting equipment is particularly suited for cyclorama and wash-lights, being able to emit coloured light directly, therefore avoiding the inefficiency of subtracting light with a coloured filter.

Red, green and blue colour additive lighting also means that filters don’t need to be replaced and this significantly reduces setting up time, removing the need to access the luminaires and other operational and maintenance requirements.

The design of LED cyc lighting includes asymmetric lenses and/or reflectors to spread the light more evenly on vertical surfaces.

LED static washlights and moving washlights with zoom capabilities are also available and can be used in both temporary and standing set designs to economise on filters and other operational requirements, offering a more flexible and dynamic way to change light colour and aiming/focussing from the lighting console.

Figure 14. Examples of LED cycs

Moving spots and profiles

Intelligent lights and moving heads typically include high power discharge sources such as HMIs to create very narrow pencil beams, gobo projections and coloured effects.

Unfortunately, the light output ratio (LOR) of moving heads is generally low, typically below 30%. It is therefore extremely important to use them sparingly and to choose the moving light that has the appropriate luminous output for the application.

Audience lighting

Similar to cyclorama lighting, blue and other colour filters used with tungsten and other white light sources over audiences are highly discouraged.

Efficient LED RGB colour mixing sources can be used to illuminate audiences evenly without the need to subtract light from inefficient light sources.

Figure 15. Blue filters with tungsten lighting is not an efficient way to illuminate audiences

Set decoration

LEDs and fluorescent backlighting have been already widely used in TV studios for set decoration and practicals. For these applications it is important to consider lighting efficiency while designing the set, borrowing skills from architectural lighting techniques.

It is also important to consider when the set decoration equipment is required and avoid turning it on when not needed.

Like lighting, video display equipment and projectors should be switched off when not in use. For this reason, it is good practice to include a switching control for displays, practicals and set decoration lighting in the control room.

Power-hungry, large LED media screens should be kept off during set preparation and switched on only when needed.

It is also encouraged to switch off smoke and haze machines. Of course, during rehearsals everything needs to be ready to go at short notice, but during set preparation and other stage operations it is possible to economise.

Lighting control and dimming

Smooth dimming of key lights and exact control of colour mixing are of paramount importance in TV studios.

Lighting dimming technology has evolved during the past 20 years and reduced the size of the components significantly.

With incandescent lighting, dimming control has been carried out using large DMX enabled dimmer racks located in dedicated rooms. Phasing out of incandescent lighting in favour of low energy lighting technologies will make the dimmer racks and dimmer rooms obsolete.

Discharge, LEDs and fluorescents now include integrated control gear that does not require separate dimmer rooms. For modern types of tungsten halogen luminaires, remote dimmers can be used; these can be compact and installed in mobile racks.

The power and data distribution network and control rooms will need to be redesigned and rewired with a different approach, that will have an impact on working practices. Rewiring the lighting rigs for DMX control can be avoided in some cases by using wireless dimming or carrying the data signal through the mains.

9/ Light source performance parameters

Colour characteristics

Light sources emit light with **different spectral compositions**: the emitted radiation within the visible field – comprised approximately between 400 and 700 nanometres – can be different for each wavelength. This spectral radiation emission is then interpreted by the eye or TV camera in combination with the reflected spectrum of the various set surfaces, props and talent skin, following the laws of the trichromatic theory of colour vision.

It is possible to distinguish between monochromatic light sources (i.e. sources emitting within a narrow wavelength range) and white light sources. White light is an emitted radiation that has continuity within the spectrum, and therefore the capability of rendering well the spectral surface reflectivity.

Colour is not definable as an inherent property of objects: it depends upon the illumination, the interaction of light with materials and the observer.

The human visual experience is different than the captured vision of a TV camera: these two “observers” have different types of photoreceptors, and therefore different experiences of light.

White light is not all the same: in fact, **different white light sources emit different spectra.** If considered from the spectrum continuity perspective, only tungsten, xenon arc and plasma light sources offer continuous spectra in the visible range, although their spectral compositions are different.

All the other low energy lighting technologies provide a lighting spectrum that is discontinuous, for which the same colour sensation (chromaticity coordinates) can be obtained by almost infinite combinations of spectral emissions.

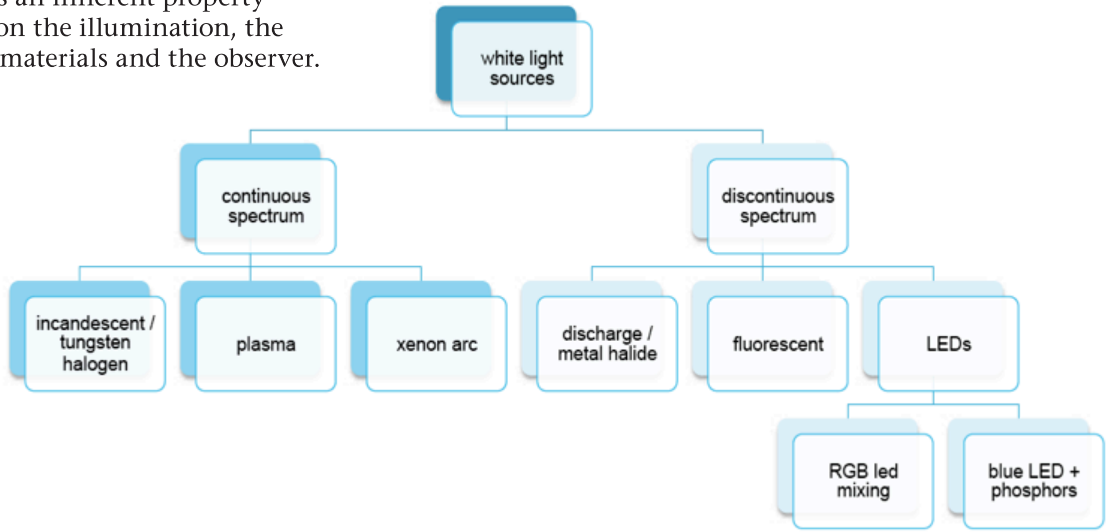


Figure 17. Classification of white light sources according to the emitted spectrum

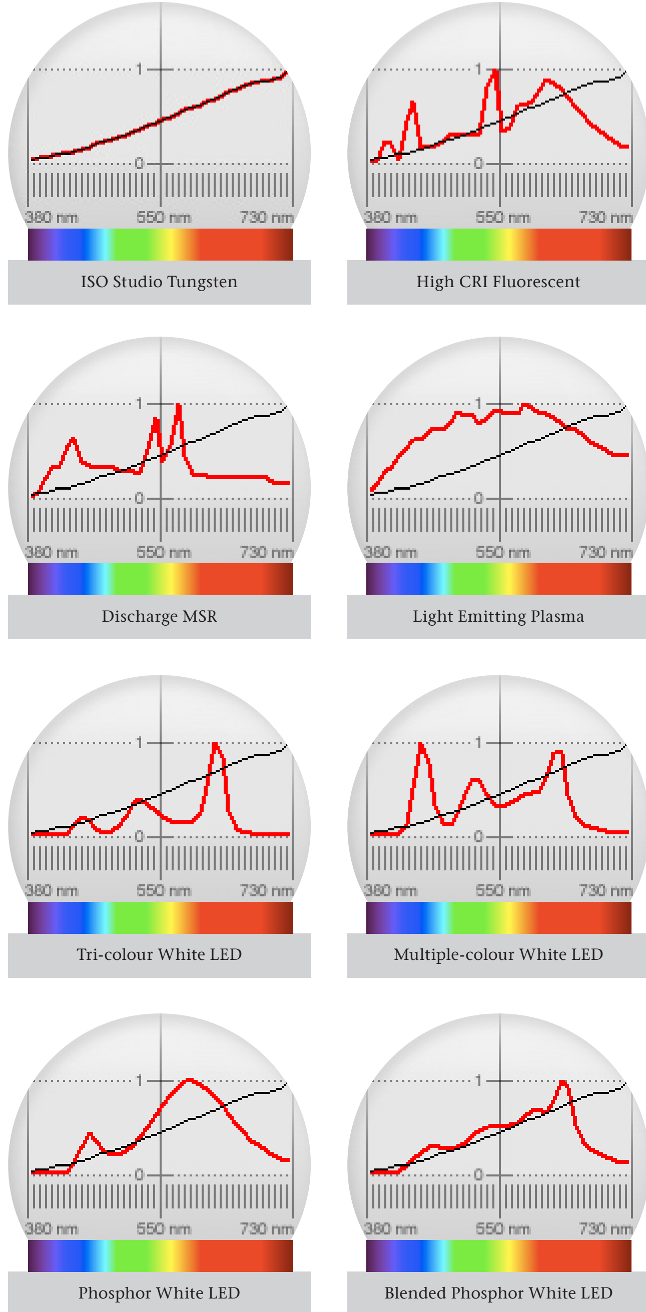


Figure 16. Spectral composition of light emitted by different white light sources used for television lighting

Light colour is the colour of the light emitted by a lamp. Light colour can be expressed using x,y chromaticity coordinates in a standard colorimetric system. For white light colours it can also be given as the colour temperature.

In the International Commission on Illumination (CIE - Commission Internationale de l´Eclairage) standard colorimetric system, the colour of light is calculated from the spectral composition and represented in a continuous, two-dimensional diagram (Figure 18).

The design of the diagram includes a coloured area that contains every possible real colour. The coloured area boundary is a curve that includes the chromaticity locations of the completely saturated (monochromatic) spectral colours.

At the centre of the area is the point of least saturation (neutral white). All levels of saturation of one colour can be found on the straight lines between its chromaticity location and the neutral white point. Similarly, all mixtures of two colours can be found on a straight line between the two chromaticity locations.

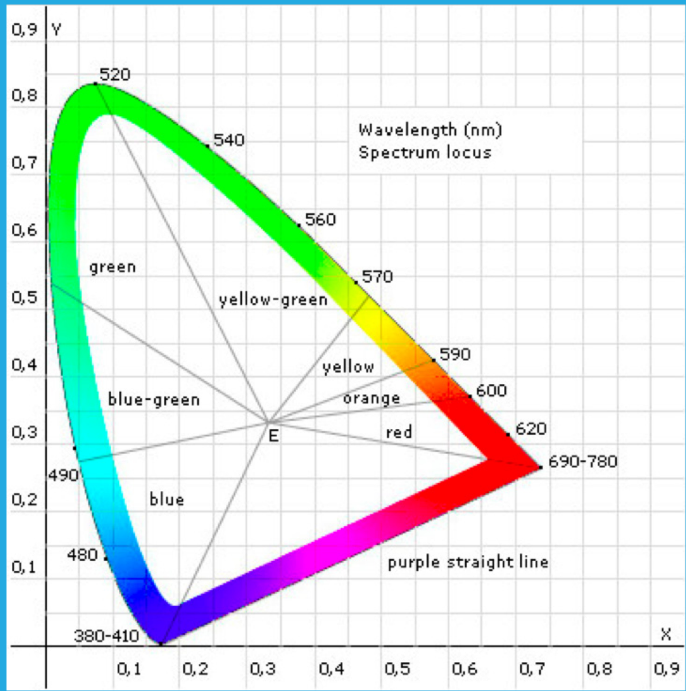


Figure 18. CIE standard colorimetric diagram

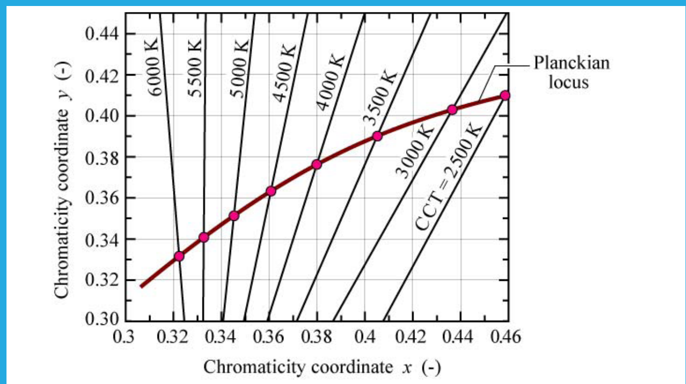


Figure 19. Planckian locus

A black body is an idealized physical body that absorbs all incident electromagnetic radiation. Because of this perfect absorptivity at all wavelengths, a black body is the best emitter of thermal radiation.

The Planck's curve (or Planckian locus shown in Figure 19) contains the chromaticity locations of the black body radiators at all temperatures.

Tungsten incandescent and halogen sources are black body radiators and their chromaticity at different temperatures lies on this curve.

Chromaticity locations of other light sources lie near to the curve. For this reason, starting from the Planckian locus, a series of straight lines of the closest colour temperatures has been added. These lines allow identification of the closest colour temperature for the colours of light sources that are not incandescent.

With discharge, fluorescent and LED sources it is possible to design the spectral emission to match a certain **colour temperature** (measured in Kelvin - K), and the closer the chromaticity is to the Planckian black body locus, the more similar the perception will be to an incandescent source. This is the reason why with non-incandescent sources it is necessary to introduce the concept of *correlated colour temperature*.

White colours of light are divided into three main groups (see Figure 20):

- the warm white range (ww) with the closest colour temperatures below 4000K,
- the neutral white range (nw) between 4000 and 5000K, and
- the daylight white range (dw) with the closest colour temperatures above 5000K.

Although the correlated colour temperature can be similar to that of a tungsten source or match the daylight colour temperature, the spectral composition also has an effect on colours: **if a light source lacks a particular wavelength in its composition, that colour could not be rendered**.

The same applies to TV camera sensors: for instance, the typical spectral response of a charge-coupled device (CCD) image sensor has three noticeable peaks and two discontinuities (see Figure 21).

The **colour rendering index** (indicated as CRI or R_a) gives a simple measure of the fidelity of a light source to display the chromatic properties of objects.

It is related to human vision and calculated by comparing on 8 or 15 test samples (see Figure 22) the colour rendering of the test source to that of a "perfect" source, which is a black body radiator for sources with correlated colour temperatures under 5000 K, and daylight above 5000 K. Although TV cameras' chromatic responses are different than the one of the human eye,

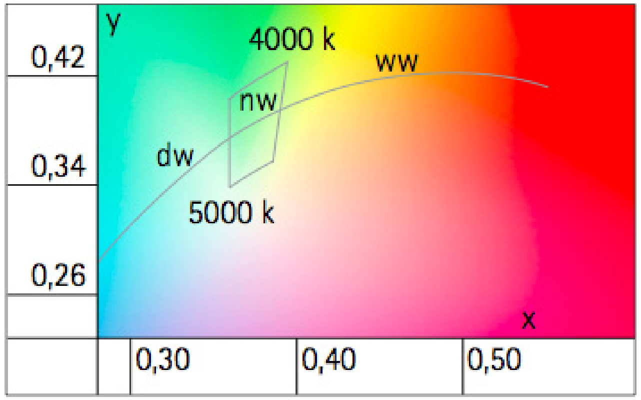


Figure 20. Main groups of colour temperatures

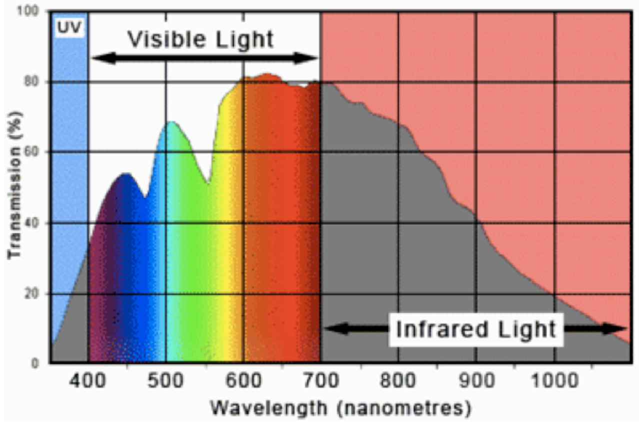


Figure 21. Typical spectral response of a CCD image sensor

Figure 22. Standard (first row) and additional test samples used to derive the colour rendering index

Dimming and colour

Dimming is another area where spectral composition of light and perceived appearance can make a significant difference.

For the incandescent light sources, dimming implies moving the chromaticity coordinates along the Planckian locus: the effect is perceived both as a change of intensity and a colour shift between “cooler” and “warmer” whites, with the limitation that tungsten will melt around 3700K and therefore is not able to reach “cooler” colour temperatures.

For discharge sources, dimming for TV studio applications can only be via mechanical shutters, therefore the colour temperature and colour rendition qualities are maintained.

Fluorescent light sources typically show colour shifts towards either the green or the magenta/pink side of the chromaticity chart when dimmed.

Similarly to fluorescents, LEDs can show a noticeable colour shift during dimming. This depends largely on the dimming methodology: with Pulse Width Modulation (PWM) dimming, the colour shift is generally far less noticeable than with analogue current variation dimming (Figure 23).

The perceived change in colour can be defined using the MacAdam ellipses. These are the regions plotted on the colour space diagram showing where colours are perceived to be the same by the average viewer.

Limiting the colour variation to two MacAdam ellipses or less can ensure that the colour shift will not be noticed. However, current recommendations and international standards allow a much higher variance of 4 or even 7 MacAdam ellipses for applications where the illuminated target has respectively a low or high colour variation.

MacAdam ellipses are also extremely important for LEDs to understand the colour variance within a certain luminaire or within a batch of luminaires.

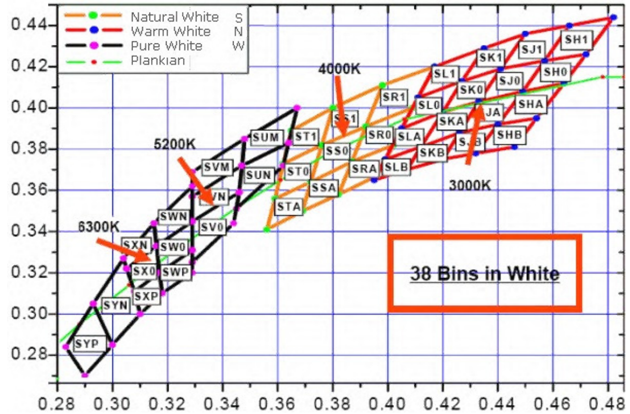


Figure 24. Example of white LEDs binning

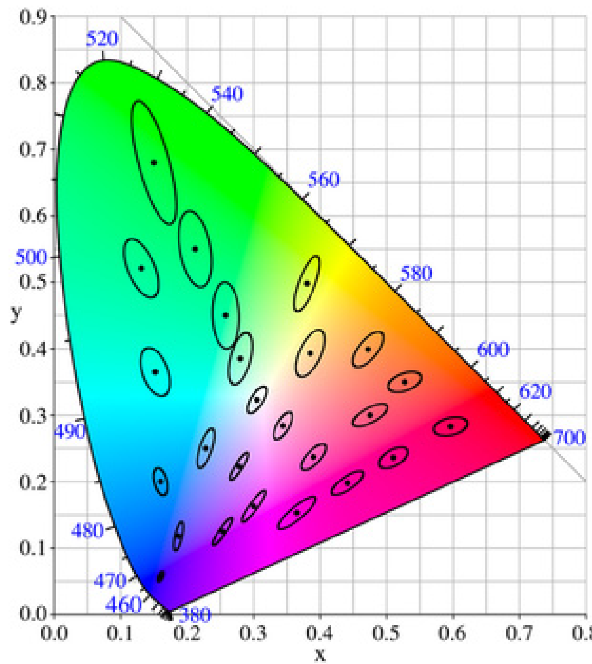


Figure 25. MacAdam ellipses for different chromaticities

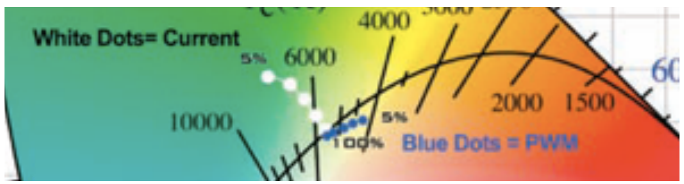


Figure 23. Colour shift for current and pulse width modulation dimming for LEDs

BBC research for the characterisation of colour

The *Colour Rendering Index* (CRI) is the only currently standardised metrology available (from the CIE, the International Commission on Illumination) for quantifying lighting quality for colour rendering.

Unfortunately it is far from ideal for a TV environment because:

- three of the more-saturated test colours lie outside the TV colour gamut,
- CRI is only defined for light sources that are approximately white,
- CRI has a discontinuity in the measurement technique for light sources with a correlated colour temperature below and above 5000K,
- CRI does not always correlate well with subjective colour rendering, particularly for light sources with spiky emission spectra such as fluorescent lamps or white LEDs.
- it relies on the outdated, perceptually non-uniform, CIE 1964 colour-space,

Figure 26. Colour Checker Chart

- we do not know yet how (or even whether) the numbers it produces correspond to the accuracy of colour reproduction in a TV system, since it is designed for human rather than camera vision.

Nonetheless, at the current immature state of the market in low-energy TV lighting products, CRI gives a first indication of which lights are most likely to produce reliable results on TV.

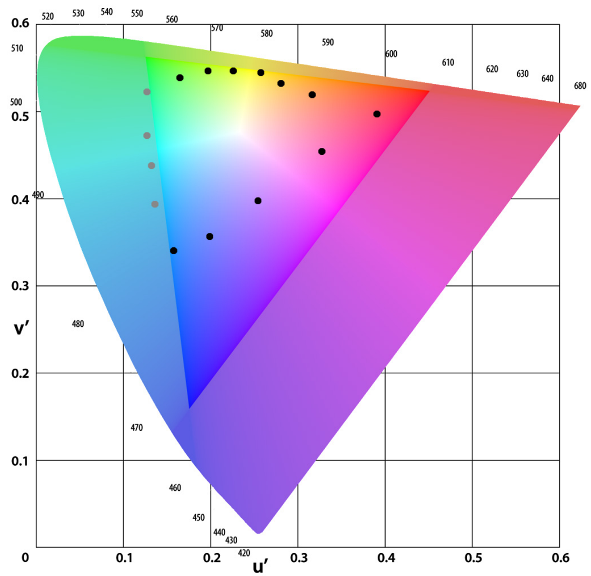
A draft from PLASA (*Recommendations for Measuring and Reporting Photometric Performance Data for Entertainment Luminaires Utilizing Solid State Light Sources*), uses the *Colour Quality Scale* (CQS) developed by the National Institute of Standards and Technology (NIST).
This is clearly a step forward compared to CRI for visual appearance under LED lighting, but still does not address the TV lighting requirements.

The BBC pioneered some research with the development and proposal of a *Television Lighting Consistency Index* (TLCI) in the 1970s and '80s, which now needs to be updated for modern camera channels. This research is now being taken forward by the EBU (European Broadcasting Union), with the establishment of a working group being imminent, possibly under BBC chairmanship. The major work still required is to define a modern "standard camera" colorimetric model.
The aim is to produce an EBU recommendation on lighting measurement, within about a year, and then possibly take this forward for international standardization though the CIE.

The TLCI specifically quantifies the quality of colour reproduction though a standardised TV camera and TV system of a series of standard test colours. It considers the differences in reproduced colour which would be observed for each of the test colours, comparing the light source under test with reproduction under standard lighting conditions, doing so through the measurement of the spectral characteristics of the light source.

It is proposed to use the test colours of the familiar "Macbeth ColorChecker" chart (Figure 26) for this work.

The BBC's R&D Department has advised that until such a TV-specific measurement method is available, it is highly advisable that **proposed light sources should be tested in a studio environment using the cameras with which they will operate**, observing a variety of colours of set, costume/clothes and skin tones, so that the future users of an area where these lights are proposed for use can ensure they will be happy with the colour rendition. There is a special need for care and testing where two different light sources are to be mixed.



CIE 1976 diagram, showing HDTV (Rec 709) Gamut, and CQS test colours

Figure 27. The diagram shows the HDTV (Rec. 709) colour gamut, using the CIE 1976 Uniform Colour Space (u′, v′). Also shown are the test colours used by CQS and PLASA, as rendered with standard D65 (daylight) lighting.

Energy and luminous efficacy

Only a small portion of the emitted radiation is useful for vision: also the eye is sensitive to radiation at each different wavelength in a different way. For this reason **the light output useful for vision is measured in lumens**, a special unit that accounts for this selectivity. **The power needed to produce light is measured in watts**.

By counting the number of lumens emitted for each watt of supplied power, it is possible to derive the **luminous efficacy of a light source**, measured in **lumens per Watt (lm/W)**. This value is an important parameter to assess the efficiency of a light source technology, but it should also be read in conjunction with the overall luminaire output ratio to get a definitive judgement on a lighting product.

The luminous efficacy of light sources has increased dramatically through time, with fluorescent, discharge, induction and LED sources currently leading the way to a less power hungry future.

Lamp life

Every different lamp technology has a unique mortality curve that depicts its average rated life.

Lamp life is typically expressed as the **number of hours when 50% of a large group of test lamps have failed**, when operated at nominal lamp voltage and current. Shock, vibration, frequent on-off cycles, overvolting, power surges, obstructed ventilation, defective lamps, and other longevity-threats are not factored in.

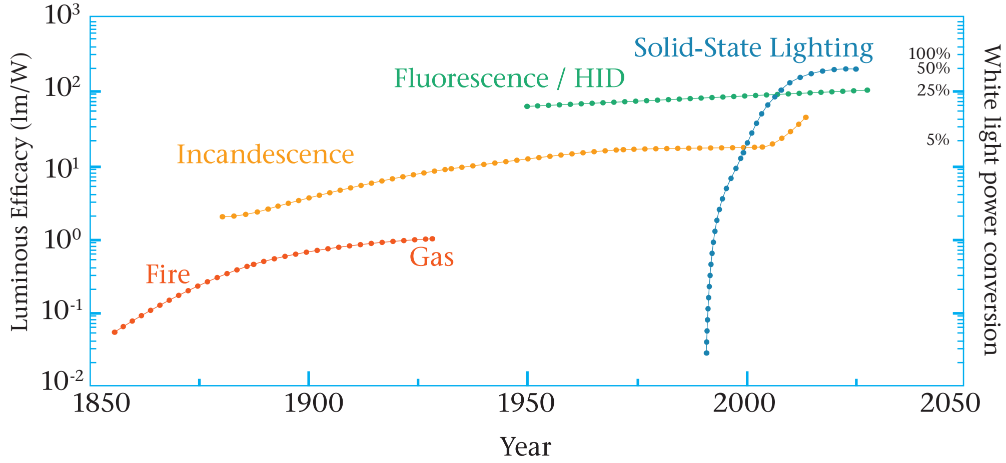
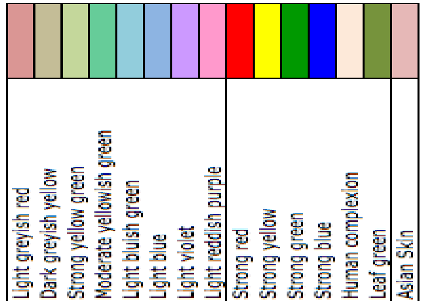


Figure 28. Improvements in luminous efficacy for light sources between 1850 and beyond 2011

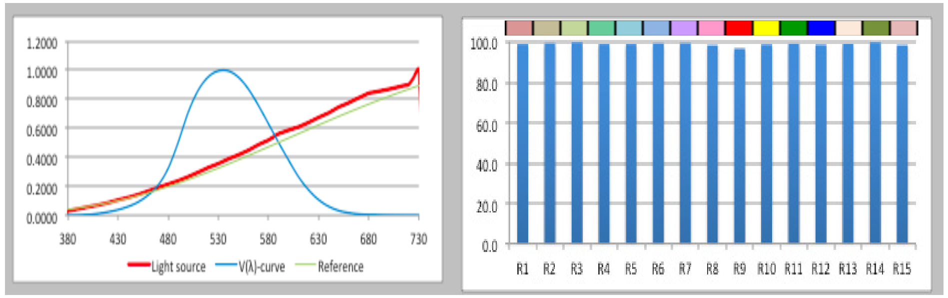
Light source type	**Luminous efficacy (lm/W)**	**CCT / dominant wavelength**	**Colour rendering index (CRI)**	**Lamp life (hours)**
Cool White LED	50-60	5,500 K	70 - 80	35,000
Warm White LED	30-40	3,300 K	85 - 90	35,000
Green LED	53	530 nm	-	35,000
Red LED	16	470 nm	-	35,000
Blue LED	42	625 nm	-	35,000
Amber LED	42	590 nm	-	35,000
Tungsten	14	2,800 K	100	1,000
Fluorescent	65	3,200 K	90	5,000
Discharge MSR	80	6,000 K	80	1,000

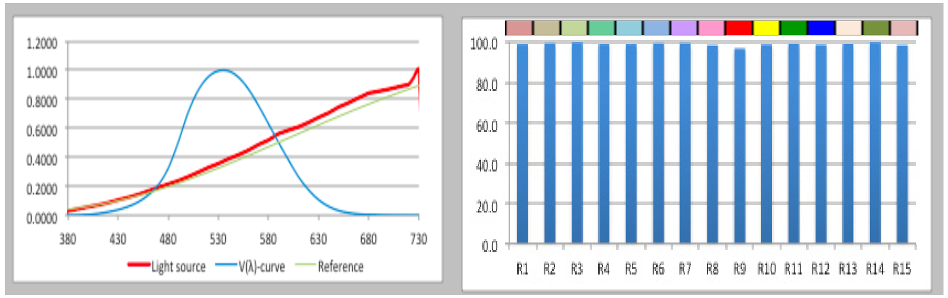
Figure 29. Typical performance characteristics of light sources commonly used in TV studios

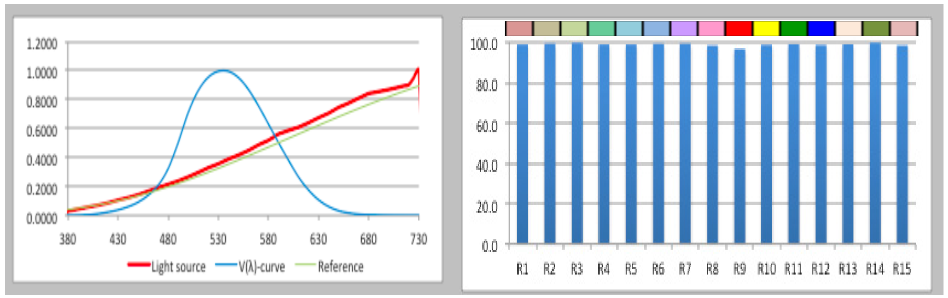
10/ Lighting Performance Comparison



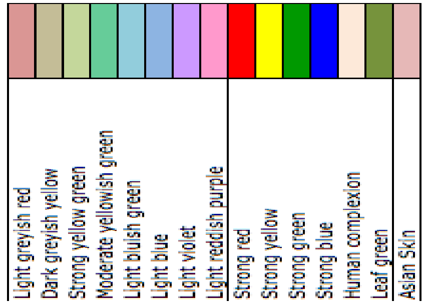
Product	Light source / CT	Power (W)	Optics	Beam angle (°)	3 m (lux)	5 m (lux)	8 m (lux)	10 m (lux)
ARRI Studio Fresnel Junior 1000 Plus	Tungsten halogen Warm white	1000	Flood	55°	2,028	730	285	183
			Narrow	11°	13,556	4,880	1,906	1,220
ETC Source Four Fresnel	Tungsten halogen Warm white	375	Flood	65°	650	234	91	59
			Narrow	20°	4,400	1,584	619	396
Dedolight DLH4	Tungsten halogen Warm white	150	Flood	48°	445	160	160	40
			Narrow	5°	9,100	3,276	1,280	819



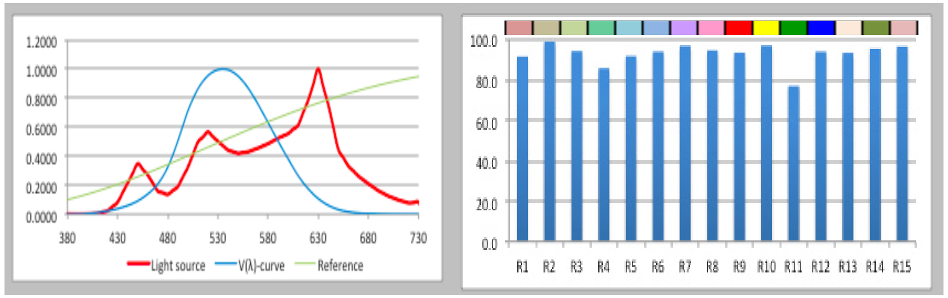


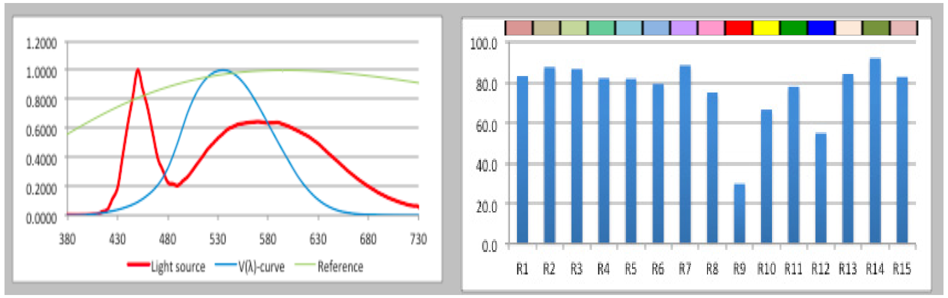


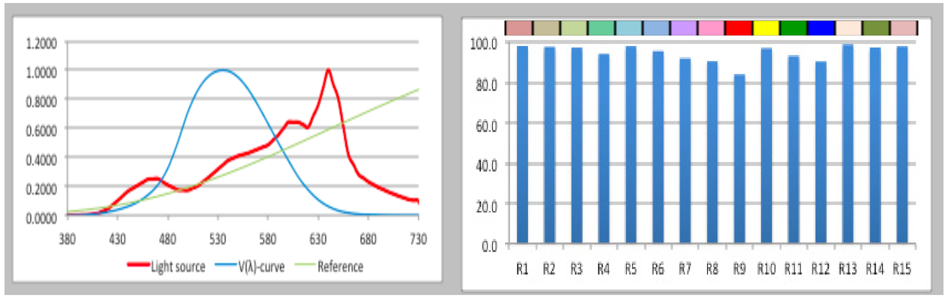
Lighting Performance Comparison



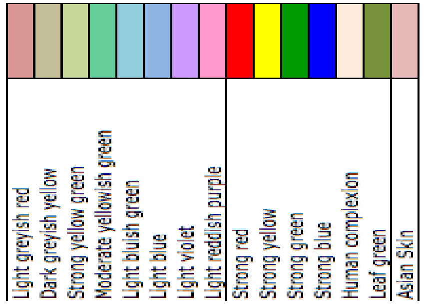
Product	Light source / CT	Power (W)	Optics	Beam angle (°)	3 m (lux)	5 m (lux)	8 m (lux)	10 m (lux)
Arri LED Fresnel	Single White LED Warm white	230	Flood	50º	749	270	105	67
			Narrow	15º	4,793	1,725	674	431
Litepanels Sola 6	Single White LED Daylight	75	Flood	70º	278	100	39	25
			Narrow	10º	2,640	950	371	238
Gekko Kezia 200	Variable LED Warm white	190	Narrow	20º	1,213	437	171	109



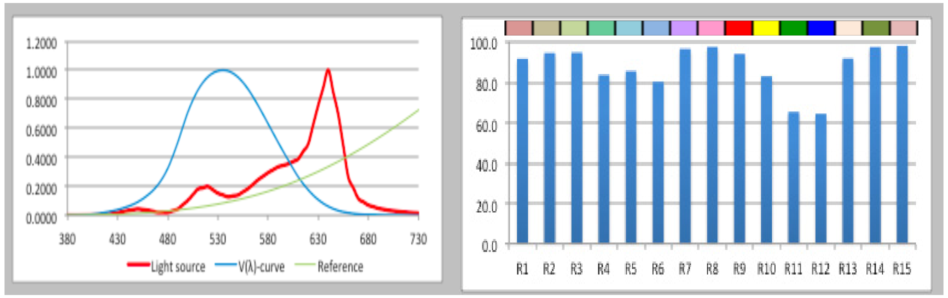


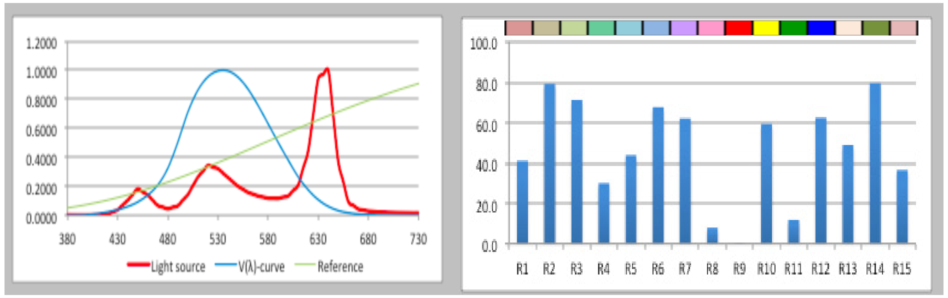


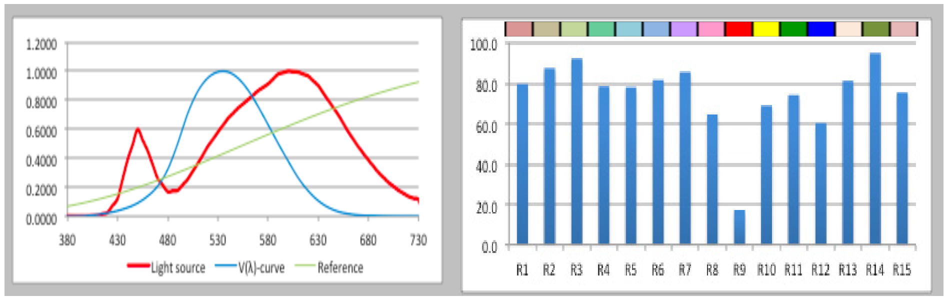
Lighting Performance Comparison



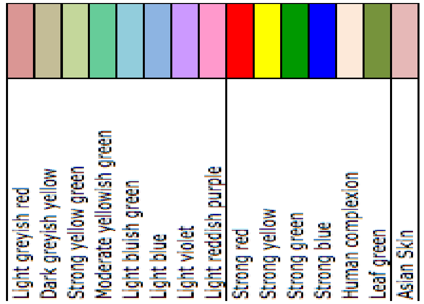
Product	Light source / CT	Power (W)	Optics	Beam angle (°)	3 m (lux)	5 m (lux)	8 m (lux)	10 m (lux)
Prism Projection RevEAL CW	Variable LED Warm white	180	Medium	27º	863	311	121	78
Selecon PL1	Variable LED Warm white	105	Flood	50º	330	119	46	30
			Narrow	10º	3,308	1,191	465	298
Robert Juliat Aledin Profile	White LED Warm white	105	Narrow	15º	4,921	1,772	692	443



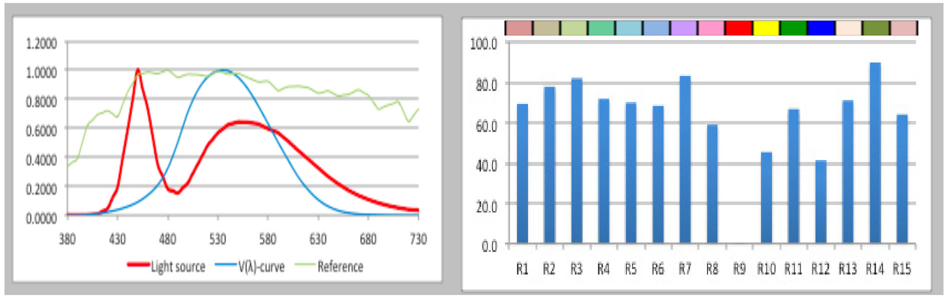


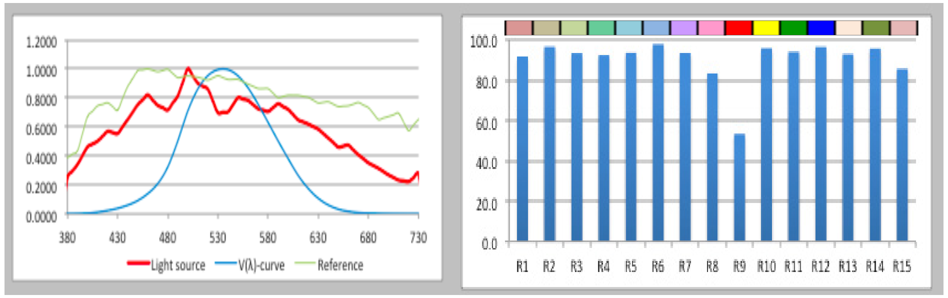


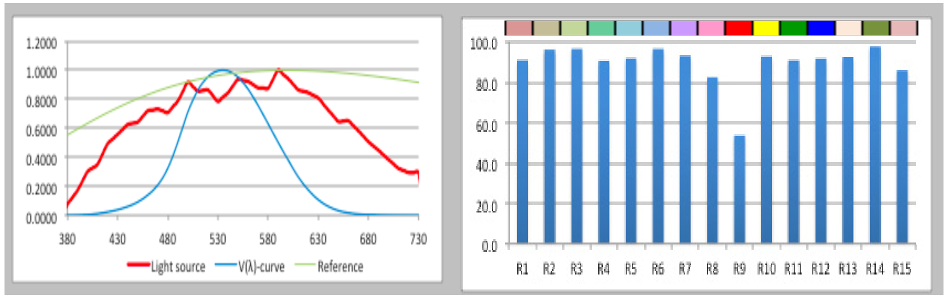
Lighting Performance Comparison



	Product	Light source / CT	Power (W)	Optics	Beam angle (°)	3 m (lux)	5 m (lux)	8 m (lux)	10 m (lux)
	**Philips Varilite VLX**	Variable LED Daylight	840	Medium	23°	4,701	1,692	661	423
	**Photon Beard Nova**	LEP Daylight	273	Flood	42°	2,167	780	305	195
				Narrow	12°	11,045	3,976	1,553	994
	**Seachanger Nemo**	LEP Daylight	320	Narrow	14°	7,964	2,867	1,120	717

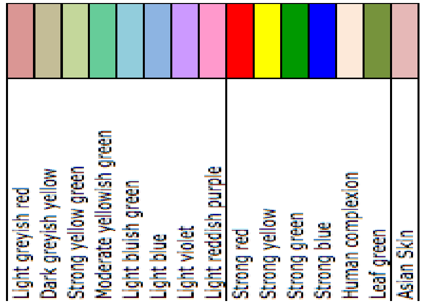


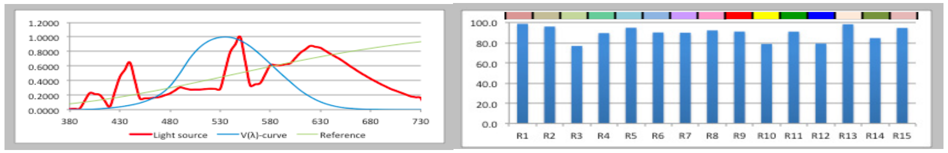


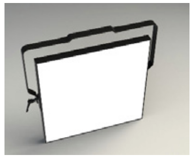


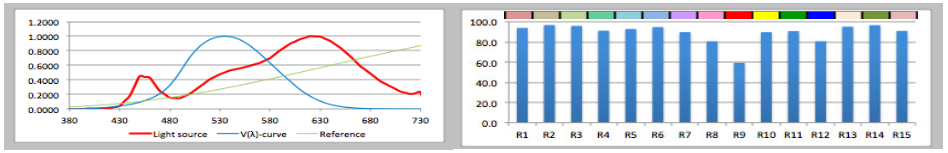
Lighting Performance Comparison

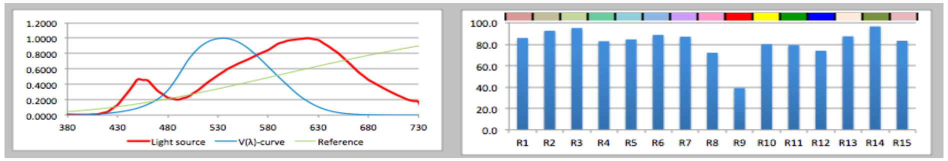
Product	Light source / CT	Power (W)	Optics	Beam angle (°)	3 m (lux)	5 m (lux)	8 m (lux)	10 m (lux)
Kino Flo Parabeam 400	Fluorescent Warm White	220	Soft-light		369	133	52	33
Galaxia KLA5955	Dual White LED Warm White	105	Soft-light		332	120	47	30
NILA JNH	White LED Warm White	65	Medium	25º	399	144	56	36
NILA JNH	White LED Daylight	65	Narrow	10º	739	266	104	67
Litepanels 1x1	White LED Warm White	47	Medium	50º	239	86	34	22
Litepanels 1x1	White LED Daylight	47	Narrow	15º	560	202	79	50

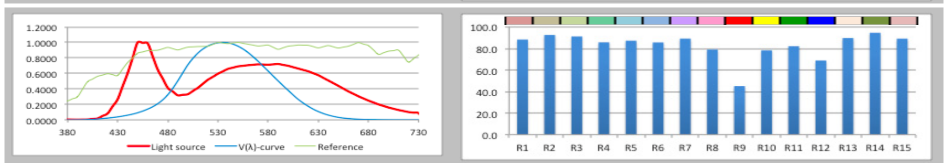


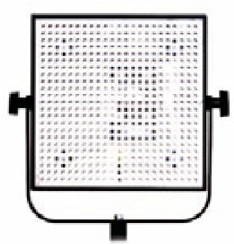


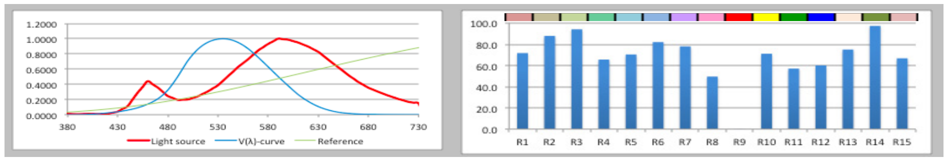


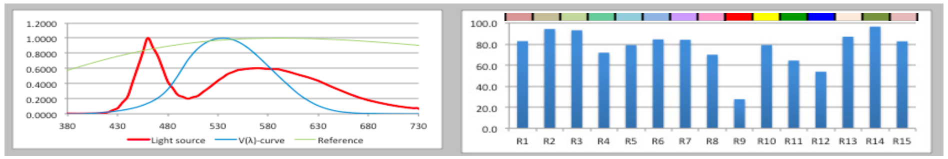




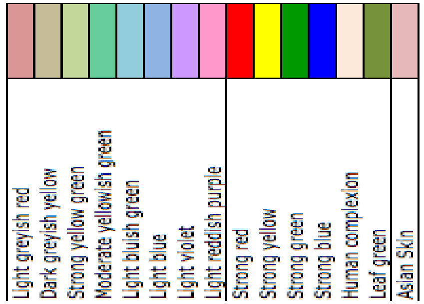




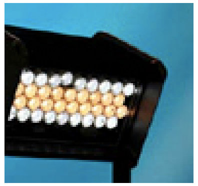


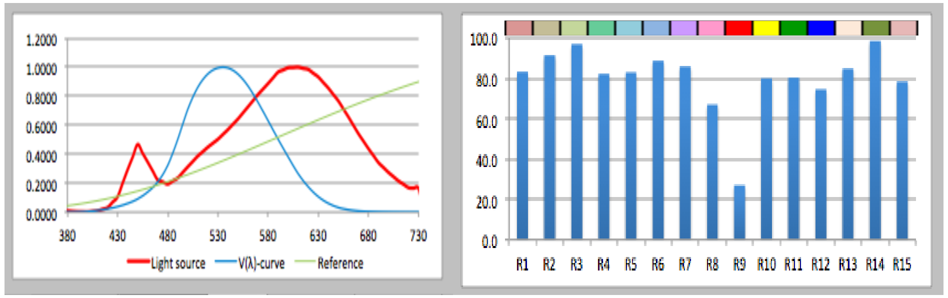


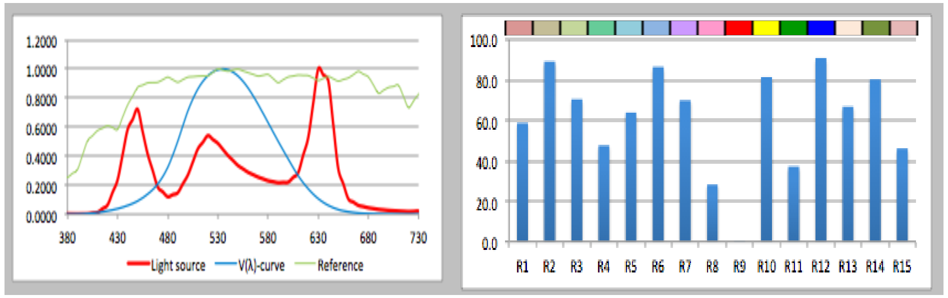
Lighting Performance Comparison

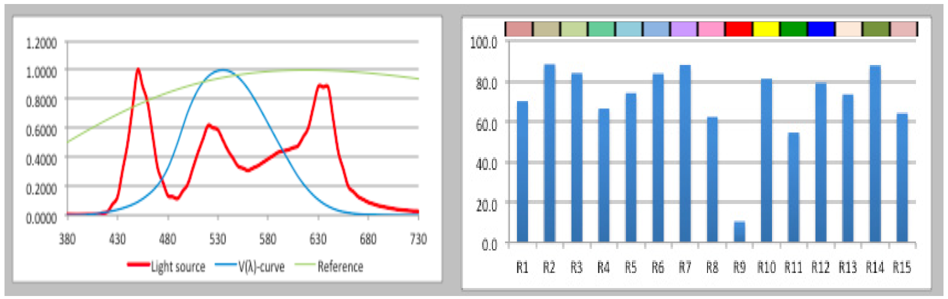


Product	Light source / CT	Power (W)	Optics	Beam angle (°)	3 m (lux)	5 m (lux)	8 m (lux)	10 m (lux)
ETC Selador Pearl 21”	Dual White LED Warm White	288	Flood	40º	1,206	434	170	109
Robin 600 LED Wash	RGBW LED Daylight	370	Flood	60º	628	226	88	57
			Narrow	15º	3,492	1,257	491	314
Chroma-Q Colorforce 72	RGBA LED Daylight	720	Medium	23º	982	354	138	88









“This is an exciting time for the lighting industry and we are delighted to foster and embrace new technologies and techniques at the BBC”

Sally Debonnaire, *Controller Production Operations*