

Entertainment Lighting and Future Lighting Regulation: The Need For Specific Exemptions

A Briefing Document prepared by the Association for Lighting Production and Design (ALPD) and the Professional Lighting & Sound Association (PLASA) <u>www.thealpd.org.uk</u>, <u>www.plasa.org</u>

10th February 2022

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1. INTRODUCTION AND CONCERNS

Entertainment lighting is a term used to describe the use of lighting in live and recorded events - theatre productions, concerts, festivals, corporate productions, television and film.

Entertainment lighting is a critical part of the entertainment and culture sector, a sector that (in non-pandemic times) is worth around £85billion to the UK economy. Without entertainment lighting, there would literally be nothing to see.

Entertainment lighting uses specialist equipment, quite distinct from equipment used for domestic, commercial or industrial lighting. This equipment and the way it is put to use is very efficient: just the right amount of light is directed to exactly where it is needed for just exactly as long as it is needed for.

However, the nature of this equipment and its optical design means there are limits to the efficiency any individual lighting fixture (which may be a fixture with a removable light source, or a fixture with a fully integrated light source) can achieve - not through lack of will on the part of the equipment's designers, but because of the limits of science and technology.

No current entertainment lighting fixtures or light sources can meet the requirement of 120lm/Watt proposed as the goal for the new UK Ecodesign lighting regulation from 2023.

Manufacturers see no possibility of producing entertainment lighting fixtures that can meet the proposed requirement within the timeframe proposed for the new regulation, or some time beyond.

While accepting that this proposal is a starting point for further discussion, it is important note that the effect of this requirement being imposed on entertainment lighting equipment would be calamitous.

Existing lighting fixtures would become obsolete as the light bulbs they rely on became unavailable.

No new fixtures would be available to replace them.

Venues would - quite literally - go dark.

The art of entertainment lighting - a specialism which British practitioners are renowned for worldwide - would suffer, and the productions - theatre, live event and film - which rely on these practitioners and this technology would either suffer from a loss of quality, or would re-locate to parts of the world where suitable technology was still available.

The exemptions in place in the current Ecodesign lighting regulations were hard won, but recognised as fair and important. They have prevented exactly this kind of calamity across Europe. and, for now, in the UK. It would be unfortunate if this same calamity were now to occur in the UK alone. Suitable exemptions for entertainment lighting in any new UK regulations would prevent this.



2. AN INTRODUCTION TO ENTERTAINMENT LIGHTING

For every show or event, the lighting will be custom designed for that production, and unique to it. The aim of the lighting goes far beyond letting the show be seen. It defines the visual identity for the show, in a way that varies from one genre of production to another and from one show to another.

In **theatre productions** (plays, musicals, opera, dance) lighting will shape the performance venue, transforming it from a bare, brightly-lit space into a highly focussed stage that sets the feel and the atmosphere of the show.



Red: a bare stage... ... transformed into an artist's studio. Only the light has changed.

Depending on the style of the show, that might be defining the location and time of day. It might allow changes of location or time instantaneously, in a way that would not be possible by changing real, solid scenery. It might be more abstract than that, shaping the mood of the show in ways that audiences might only subconsciously be aware of. It might be calm or dramatic, safe or scary. It can control where the audience look, where they don't look; it can shape what the audience sees, but also how they feel.



Same set, transformed just by lighting - the play Equus

The most iconic moments of the most iconic shows - many of which are productions created in the UK that have gone on to enjoy great artistic and commercial success around the world - are defined by their lighting.



Iconic productions, iconic lighting - clockwise from top-left: Les Misérables, An Inspector Calls, Harry Potter and the Cursed Child, Six, War Horse, The Phantom of the Opera



In **concerts and live events**, ranging from music festivals to epic spectaculars such as opening ceremonies of Olympic Games, the lighting has a different purpose. It is there to provide energy and drive to the performance, to connect performers and audience, to conjure spectacle in the air surrounding the performers. Here, too, the iconic moments you remember are created, shaped and defined by their light. New light-based entertainments continue to appear, notably the Christmas Light Trails that have thrived in recent years.



Clockwise from top left: London 2012 Opening Ceremony; Adele; Sam Smith; Stormzy; Coldplay; Christmas at Kew

In **film and television**, lighting lets the images be captured by the cameras. Without suitable lighting, it would really just be radio! But it still also has to achieve all of the above, the precise needs depending on the show - the drive and spectacle of *Strictly*, the drama of *The Crown*, the joy of *Bake Off*, the creation of live effects backgrounds or green screens into which effects can later be inserted on the likes of *The Mandalorian*.



L-R: The Mandalorian; Strictly Come Dancing; The Crown

Lighting for all of these events - from the smallest amateur plays to the biggest spectaculars - is created by specialists in their craft. The job titles vary between areas - lighting designers for live events, lighting directors in television, directors of photography in film - but their role is the same in every case. They must decide what the show should look like, then work out how to create that look using the specialist entertainment lighting tools at their disposal.

If those tools were no longer to be available, they would no longer be able to do their work.

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3. LIGHTING AND THE CREATIVE INDUSTRIES

Britain is renowned world-wide for its creative industries including live and recorded performance, and for the skills and talents that fuel those industries. Shows created in Britain often go on to play to great success around the world. Britain has become a key production resource for international producers making films and television shows.

Though the numbers have been distorted by the pandemic over the last few years, this is a highly successful sector:

- the Business Visits and Events Partnerships estimates that taken together, all forms of live events generate £85billion within the UK, with the cultural sector (film, tv, music, theatre) worth £26.8billion to the UK in 2016.
- In theatre alone, revenue from ticket sales usually exceeds £1billion annually.
- Total concert attendance in the UK during 2016 was 27 million people, with a £4billion direct and indirect spend on live music.
- £2.37billion was invested in film and high-end TV production in the UK during 2017. This figure has increased dramatically during the pandemic, limited only by a shortage of suitable studio space even after many buildings not traditionally used for this purpose have been converted to temporary studios.
- The contribution of the Cultural Sector has been growing steadily and reliably (4.4% growth in 2015-2016 vs 3.5% in the wider economy, 27.1% in 2010-2016 vs 22.7% in the wider economy).
- For every £1 of public funding of the arts and culture, £5 of tax is contributed by the arts and culture industry.
- There are more than 241 professional theatres in London; hundreds more across the UK, thousands more venues of all types from stadia to school halls. The smaller venues provide the training and experience from which people move to successful careers in larger venues and on larger events.
- There are around 1 million people working in this industry.
- Almost £5.2 billion of arts and culture-based goods and services were exported from the UK in 2013.
- The UK creative industries as a whole are said to represent one quarter of the UK economy; the House of Lords Select Committee on Communications noted in May 2017 that "the theatre industry is rightly hailed as one of the UK's cultural and economic success stories."



Performance lighting is a key part of every type of live show and event. During discussions on the EU Ecodesign regulations in 2018, it was clearly indicated by major film and television producers that if suitable lighting tools were not available to them in the UK or Europe, they would move production elsewhere.

The British lighting practitioners and suppliers who design and supply the lighting for all of these events are accepted as world-leaders in their field. The shows they create travel the world, and the skills of key designers such as Patrick Woodroffe (London 2012 Olympics, The Rolling Stones), Paule Constable (*War Horse, Les Misérables*) and many more are also in demand across the world for productions created locally in other countries.

Entertainment lighting is an industry at which Britain leads the world.

It could suffer incredible damage were the tools it relies on no longer available in the UK. With the currently suggested intention for a simple rule requiring light sources to meet 120lm/W by 2023 and 140lm/W by 2025 this is a real possibility - because **no specialist entertainment lighting fixtures can currently meet those requirements**. Not because of a lack of will, but because of the limitations of science and optical design.



4. ENTERTAINMENT LIGHTING - TECHNICAL EVOLUTION

Progress in lighting: candle, gas, electricity, directional spotlights, LED fixtures

From the moment performance moved indoors, some form of artificial light has been required. Over time that has evolved from candles (the very structure of plays from this era, with numerous short acts, results from the relatively short time a candle could burn for) to gaslight to electricity.

The entertainment industry has never been afraid to adopt - and to invest money in - new lighting technology as it has arrived. Imagine the costs involved in converting a theatre to each of these new technologies! Though for theatre owners, electricity provided one key advantage over its predecessors: your theatre was much less likely to burn down!

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For lighting practitioners, electricity offered countless new possibilities, particularly the ability to have lights that could, by virtue of wrapping the light bulb in an optical system of reflectors and lenses, project light over a distance, and precisely control where on stage the light landed, what it illuminated and what it didn't, and what colour it was (using colour filters) as well as its intensity, using external dimmers. The profession of lighting designer was established, and new manufacturers (including for many decades the British company Strand Electric) produced innovative new lighting equipment and sold it around the world.

Today lighting practitioners continue to adopt new technology as it becomes available and reaches a standard of performance that matches or exceeds its predecessors. Currently this shift is moving entertainment lighting rapidly away from the tungsten filament light bulbs and discharge 'arc' light bulbs that have served it so well for many decades, to the use of more energy-efficient LED technology.

Lighting designers for shows don't always get a choice as to what equipment they use - they may be limited by equipment that a venue owns, or that a rental company has available, or by budget. But given a free choice, they have overwhelmingly been moving to LED sources. A chart showing different fixture types used on big musicals at the same London theatre since 1993 indicates that the new technology took the lead from the old in about 2014.



While the entertainment lighting industry still values existing technology, particularly the full-spectrum light from tungsten sources that is still unmatched by any of the new technology, it is also not afraid of new technology where it offers new possibilities. But new technology is expensive, so switching to it must be justified by the balance of new possibilities it brings, environmental considerations, and cost.

It is very easy to make a seemingly obvious statement that LED technology is more efficient (less power for the same light output) than tungsten or arc light sources. But there are also broader factors which require careful consideration before coming to any conclusions about the overall environmental impact of these products in use in real-world conditions.



5. ENTERTAINMENT LIGHTING - CURRENT FIXTURE TYPES

Entertainment lighting fixtures generally have some key requirements: directional beams, precise beam control, high colour rendering with a full colour spectrum, good fade performance (smooth, step-free even at the 0-1% step), silent or near-silent operation (particularly for fixtures used in theatre), consistency from fixture to fixture, reliability/ease of maintenance, a long working life, and affordability and availability, all of which contribute to the challenge of making them achieve 120lm/W.

Fixtures can be broadly divided into four categories of light output, which are independent of the type of light source used. In most cases the fixtures are available in manually set versions which will be locked to one position for a show, versions that can be manually operated live during the show by a human operator (such as followspots), or motorised versions that can have their parameters adjusted remotely from a computerised lighting control system. Those categories are:

Spotlights:



Fixtures generating a tightly controlled, clearly defined directional beam of light where the light passes through a focal point within the lighting fixture. The beam of light can be varied in size by adjusting the lensing or using an internal iris located at the focal point to constrain the beam, or it can be shaped using shutter blades to create shapes with straight edges, or inserting a cut-out or glass pattern called a gobo to project an image of that pattern. Accessories can add the ability to change the colour of the light. The followspots projecting circles of light that move with the star of a show are the most obvious example of spotlights. The industry-standard Source Four spotlight gave a radical improvement in spotlight efficiency on its launch in 1992, achieving 13lm/Watt where equivalent previous fixtures had managed just 5lm/Watt.

Washlights:



Fixtures generating a soft-edged beam of light, where the edges are less clearly defined and so the resulting beams of light are better able to blend together to create a continuous wash of light across the stage. Some degree of beam shaping may be available using internal or external mechanical systems. Traditionally washlights have used a Fresnel lens to achieve the softedged beam. LED versions often take different approaches using arrays of LEDs each behind an individual lens to create more compact lighting fixtures.



Floodlights:



Fixtures generating a very wide wash of light. In theatre, these fixtures may be used to light painted backcloths or similar scenery, the wide wash allowing the light to cover from the top to the bottom of the cloth even when the light is positioned very close to the cloth. In current film production arrays of floodlights are often used to light the green-screen cloths that provide a neutral background behind performers into which visual effects are later inserted. They provide a soft even light allowing multiple light sources to be blended to evenly illuminate large areas.

Beam/Effect Lights:



Fixtures generating tighter, often parallel, shafts of light which are visible over very long distances. Such fixtures are often found at events (think of the searchlights at a film premiere) or providing dramatic lighting looks in the air at concerts or on television specials - think of the beams of light behind the dancers on *Strictly Come Dancing*.

6. ENTERTAINMENT LIGHTING - CURRENT LIGHT SOURCES

The four fixture types above are generally now available using four principal types of light source: tungsten, arc/discharge, fluorescent (for floodlights only) and LED.

It should be noted here that traditional lighting equipment has consisted of a lighting fixture with an interchangeable light source - usually a tungsten or arc bulb. The majority of entertainment LED fixtures are lighting fixtures with integrated light sources. This approach allows the most precise design of the optical system, the best thermal management which is critical to the optimum performance and long life of LED light sources, and, where required, the best protection of the fixture from the elements - for example, in fixtures designed for outdoor use. A few fixtures have removable light sources, but these are generally not interchangeable with other lighting fixture types - they are removable to allow for maintenance, replacement after failure, or upgrades to new light sources from the same manufacturer.





Source 4WRD LED replacement module for tungsten Source Four spotlight

It should also be noted that, unlike in the domestic/industrial lighting industries, there are very few drop in replacement LED light sources available for older lighting fixtures. Those that exist are only available for the most popular tungsten lighting fixture, the ETC Source Four. That is the biggest selling fixture in entertainment lighting history (at about four million units of all types over the fixture's thirty year history). so there is a demand for such a replacement source. However, even these are not strictly 'drop in' replacements since they also require the replacement of part of the lighting fixture, (control console, dimmers, cabling) used to control the fixture. The replacement light source also costs as much (\pounds 570) as the rest of the fixture (\pounds 590), whereas a replacement tungsten light bulb costs just £15.

Replacement LED sources for other older entertainment lighting fixtures, which sold in much smaller numbers, are not available, and are unlikely to be available because of the very low potential demand relative to the investment required to bring them to market.

Tungsten:



Tungsten light bulbs use a metal filament heated within a glass envelope to create light. They are fire encapsulated in glass - in effect, miniature suns. The light they give out is familiar to us because as a species we have evolved with fire as our defining light source. More technically, they are a full spectrum light source, with the light including all of the frequencies of visible light in roughly even proportions. It has a rich warmth to it that newer technologies cannot yet match. Tungsten can also be dimmed smoothly and evenly,

Practically, they are familiar, easy to handle, relatively inexpensive and relatively low tech. If a tungsten fixture fails, changing the bulb usually brings it back to life.

In entertainment, they have been established as the principle light source for decades; particularly in theatre, the lighting infrastructure is usually designed around tungsten light sources with remote dimmers wired to outlets around the building to allow the levels of individual fixtures to be adjusted from moment to moment during a show using a specialist control console.

Regardless of regulation, the limiting factor to the ongoing the use of tungsten light sources is likely to be obsolescence rather than regulation, with manufacturers moving out of the manufacturer of all tungsten light bulbs at a rapid pace.



Nominal Efficiency: 11-13 lm/W within a lighting fixture, 26lm/W light source. (based on Source Four fixture)

Typical Costs: Fixture: £590 (Source Four). Replacement lamp: £15.

Current Exemption: Schedule 4 Exemptions - 3(2)(m) provides specific exemptions for key tungsten sources used by entertainment lighting, identified by their cap-type and limited to entertainment lighting use. (w)-(ii)-(bb) and (dd) provide exemptions for specific low-voltage tungsten sources used in entertainment lighting. Very high output tungsten sources (particularly those used by the film industry) sit above the 82,000 lumen limit described in Part 1 Interpretation 2(c) and so are out of scope of the current regulation.

Arc / Discharge / HID



Arc, discharge or HID bulbs (three words describing the same technology, which is also sometimes named for the make up of the chemical elements inside the bulb - HMI, MSR, MSD) use electrodes within a glass envelope housing particular combinations of gaseous elements, and then create a continuously running 'spark' between those electrodes to create a very bright light with a tiny source size. The small source size makes it easy to define efficient optical systems around this light source, since optical system become more efficient as the source size becomes smaller. Arc sources are also relatively robust because there is no fragile metal filament. Arc lamps are used in high output fixtures such as followspots, lighting fixtures used in film where high light levels are required, and in automated moving lights where their robustness is a benefit.

There are quite high running costs involved with arc lamps: when on they are always running at full power regardless of output light level (the only way of dimming them is by using mechanical dimmer flags). In addition the lamps 'age' over time, losing their brightness and colour quality within just a few hundreds of hours of operation (so typically a few months of use) and therefore requiring regular replacement. Because of this a rapid movement from arc fixtures to LED fixtures is already taking place, budgets permitting.

Nominal Efficiency: 22lm/W within a lighting fixture, 85lm/W light source (based on a Martin Mac Viper fixture, MSR Gold 1000 lamp)

Typical Costs: Fixture: £8815 (Martin Mac Viper Performance moving light) £7860 (Robert Juliat Super Korrigan followspot). Replacement lamp: £180 (HTI1000 for Viper), £110 (HMI1200 for Korrigan)

Current Exemptions: Arc sources as used in entertainment lighting are generally out of scope of the current regulation either because their lux output per mm² of projected light-emitting surface area exceeds the 500 lumen defined by 1 Interpretation 2(2)b, or for higher output sources because their luminous flux exceeds the 82,000 lumen upper limit defined in 1 Interpretation 2(2)c.



Fluorescent

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Fluorescent light sources have found various applications in entertainment lighting over the years. Their main ongoing current use is in lighting large areas of green screens, which are used as 'neutral' backgrounds on film productions into which visual effects can later be inserted behind the actors.

LED replacements for these fixtures are available and are entering service. However, the large quantity of fixtures often required for a project, and the large existing stocks of fluorescent fixtures held by rental companies, means that the fluorescent versions are still in use - particularly since it is important that the lighting across a green screen matches, so it is not possible to 'mixand-match' between older and newer fixture types. Given that fluorescent light sources are already relatively efficient light producers, suppliers can find it hard to justify the high costs involved with switching to LED fixtures.

As with tungsten, fluorescent fixtures are likely to meet a natural end of life as the fluorescent bulbs they rely on fall out of production. Since this process is already underway, it feels like forcing it to speed up through legislation will only create financial challenges for suppliers, and perhaps ultimately disrupt the production of effects-based films for which the UK is currently a soughtafter production centre.

Nominal Efficiency: 50-100lm/W depending on lamp type.

Typical Costs: Replacement lamp: £18 (55Watt 5400K fluorescent)

Current Exemptions: Schedule 4 Exemptions - 2(a) and particularly 3(2)(u) and 3(2)(w)(ii)(ff) provide exemptions for the fluorescent light sources used in entertainment lighting applications.





LED fixtures are the up-and-coming light source across all areas of entertainment lighting, and in all fixture types. Given a choice (ie. on productions where they can specify the equipment they need rather than relying on existing equipment inventories, and where a suitable budget is available), lighting designers are moving to LED at a rapid rate. As noted earlier the cross-over point between LED and tungsten/arc being the main light source on musicals took place back in 2014

While white light only LED fixtures are available, in many cases, it is desirable for entertainment lighting fixtures to be able to change colour dynamically. Two main approaches are currently in use to achieve this with LED fixtures:

- in 'subtractive' colour mixing fixtures, a white light LED source is used. The colour is then varied using motorised colour flags, usually in the subtractive primary colours of cyan, magenta and yellow, sometimes with additional colours. This allows the use of the efficient white light sources which LED source manufacturers seem to be concentrating most of their efforts on, alongside colour-changing techniques that have long been used with arc entertainment fixtures and so which are familiar to manufacturers. These fixtures tend to measure as efficient in white light, but of course become less so when used in other colours - power is being used to generate the white light but some of that light is then being 'thrown away' (filtered) to generate the output colour.
- in 'additive' colour mixing fixtures, multiple LED sources of different colours are used. With all of the sources turned on, some version of white light is created. By varying the levels of the different coloured LEDs, other colours are created. Simple systems use just the three primary additive colours, red, green and blue. Because of the limited spectrum of these coloured sources and the resulting 'gaps' in the colour spectrum they create when used together, such fixtures usually give poor colour rendering that becomes very obvious when lighting complex coloured surfaces such as multi-coloured fabrics or the human skin.



Typical spectral distribution for RGB (left) and RGB-Amber (right) colour-mixing LED sources. Areas where the lines do not overlap are effectively missing colours that the fixture cannot create; any lit object containing those colours using such a source will look un-natural.



Entertainment lighting manufacturers have taken to adding more colours to 'fill in the gaps' in the spectrum, giving better white light and a wider colour gamut. The fixture that really made LED lighting acceptable to stage lighting practitioners, the ETC Lustr2, uses seven colours (red, green, blue, indigo, cyan, amber, lime). Its successor, the ETC Lustr3, adds an eighth colour, a very deep red, that brings a magical richness when lighting human skin.



Spectral distribution for the seven-colour LED system in the ETC Lustr2

Additive colour mixing fixtures (particularly fixtures using many different coloured sources to achieve high quality white light and a wide colour gamut) can sometimes measure relatively poorly in terms of efficiency compared to white LED sources when generating white light because multiple LEDs are required to achieve the same output. However they become much more efficient when used in colours, particularly deep colours, since only exactly the right amount of each colour of light is being used at any moment, rather than having some light thrown away. This is an important distinction, and one that should to be reflected in the way any Im/Watt efficiency figures are evaluated.

The very few entertainment lighting fixtures that can meet the proposed 120lm/W efficiency standard, whether measuring the light source in isolation or the light output from the complete lighting fixture, are open-face generally strobe type LED effects that create very intense bursts of white light for very short periods of time with little or no control of the beam. They are not suitable for general entertainment lighting.

Other LED fixtures cannot meet the requirement because of the high light output required (which for LEDs usually involves multiple sources joined to behave as one, which gives a larger source area and so a less efficient optical design, a limitation known as etendue), because of the high light quality (high CRI or other measure) required, or because of the losses which naturally occur in any optical system.

Manufacturers suggest that they see no path to achieving 120lm/W for at least the next half decade, based on the product pipelines they see from the LED source manufacturers they rely on.



White Source LED Fixtures:

Nominal Efficiency: 22-46lm/W fixture, up to 84lm/W (light source) (based on a Martin Mac Encore/Mac Ultra fixtures)

Typical Costs:

Fixture: £1160 (ETC Source Four with S4WRD White replacement source) £8930 (Martin Mac Encore Performance CLD moving light) £14295 (Martin Mac Ultra - which is an LED equivalent to the arc Mac Viper)

Multi-Colour Source 'Additive' LED Fixtures:

Nominal Efficiency: around 36.8lm/W in white light in the very best fixtures (based on an ETC Lustr2 spotlight)

Typical Costs:

Fixture: £1625 - £2700 (ETC ColorSource Spot - ETC Lustr3) £3145 (Gemini 2x1 Soft RGBWW panel - television/film softlight) £10940 (Robe T1 additive colour moving light)

Current Exemptions: Although they are far more efficient than older light sources, many current entertainment lighting LED lighting fixtures, particularly those using additive colour mixing, still require an exemption from the current EU/GB Ecodesign lighting regulations. Schedule 4 Exemptions - 3(2)(I), 3(2)(n) and 3(2)(w)(ii)(aa), (cc) and (ee) provide these exemptions.

In addition Schedule 4 Exemptions - 3(2)(3)(a) and (b) provides exemptions from the current standby power requirements for entertainment lighting fixtures, which must be able to respond instantaneously to requests to change output (to time with a 'crash' in the music, say) and so cannot go into a low power 'standby' mode to reduce their standby power. This will continue to be a requirement in the future.

Future Light Sources

There is no reason to assume that LEDs represent the ultimate development of the light source. New light sources, such as laser phosphor activation, are already transferring from other fields such as car headlights into entertainment lighting, the first such product being the Clay Paky Xtylos. Care should be taken that any future regulation does not use definitions that are limited to existing light source technologies in a way that would preclude the development and use of new light sources.

7. WHY CAN THESE PRODUCTS NOT BE MORE EFFICIENT?

Entertainment lighting fixtures have the key requirements of being able to project light in a precisely controlled beam (which requires the use of an optical system), of having a good quality of light by whatever measure is used to judge the light quality (CRI or other measurement), and of having a high light output, though the actual output will vary from product to product depending on application - lights intended to be used on shows in huge stadia need to be brighter than lights intended to be used in tiny theatres.



Lighting systems involving optical systems of a reflector (to direct light from an omnidirectional light source forward) and lenses (to capture and focus that light into a controlled beam) are at their most efficient when the light source is very small because the entire optical system can be optimised around that point. As the light source grows, the entire optical system has to grow with it, and also becomes less efficient at collecting and controlling the light because it is originating from a larger volume - the system cannot be optimised around one tiny point. This effect is called etendue. Arc lamps, where the actual point of light within the bulb is tiny, allow the design of very efficient optical systems. Tungsten lamps, where the light source is the size of the metal filament, do not allow such efficient designs but filaments can still be kept relatively compact.

With LED lighting systems, there is a limit on the amount of light that can be emitted per area of LED, particularly while controlling the operating temperature of the LED. 'Brighter' LED systems usually do not involve brighter LEDs, but instead using ever-larger collections of small LEDs to give a higher overall light output. But more LEDs means the source of light is spread over a larger area, again reducing the efficiency of the optical system. The overall system may need to be made larger still to ensure correct cooling of the LEDs.

The light will then be directed through one or more lenses - in complex moving lights this can sometimes be thirteen or more separate lenses. Any lens produces a light loss, and so the light finally emitted from a lighting fixture will be less than that measured at the light source in isolation.



Bridgelux V-Series COB, Luxeon Rebel (not shown at the same scale)

You will be aware that some white LED sources used for domestic and commercial lighting can achieve the 120lm/W requirement. The Bridgelux V-Series COB (chip-on-board) white light range can achieve up to 182lm/W measured in isolation. However this is a physically large package unsuitable for use in a fixture where the light is required to converge at a focal plane. The physically smaller Luxeon Rebel range, which is much more suitable for this kind of fixture, peaks at around 100lm/W measured in isolation, so less if the measurement was of the output of a complete lighting fixture. But note also that these are examples picked just to indicate high relative Im/W efficiency. There are many other considerations when choosing LED sources for these lighting fixtures, particularly light output, colour quality, heat management and source life, which influence the choice of LED sources used.

It is worth noting at this point that there has been little or no discussion regarding the future UK lighting regulations as to exactly what is being measured - the light at the light source, or the light coming from the fixture. In the case of entertainment lighting fixtures, many of which use a light source that is an integral part of the fixture, this distinction is important. And if measuring the light source, just what is to be measured: in an additive-colour lighting fixture consisting of eight different colours of LED, are you measuring the LED array as a whole, or individual colour groups, or even individual LEDs?



8. PERFORMANCE LIGHTING AND OVERALL ENERGY USE



The Olivier Theatre at the National Theatre in London

Entertainment lighting fixtures are rarely used individually. Lighting rigs for entertainment productions of any type rely on large quantities of specialist entertainment lighting fixtures. For the largest shows, it can feel like the lighting rig is enormous.

Looking at the size of these rigs, it is easy to assume that these shows consume large amounts of power.

This is not the case.

Taking a theatre production as an example: each lighting fixture will have a specific purpose, whether that be providing a broad brush-stroke of light to a particular area of the stage in a particular colour, or providing a very tight pinpoint of light to a particular moment, or providing some other particular effect such as light through a door or window.

It will rarely, probably never, be the case that all of these lights are on at the same time

In addition, because each lighting fixture has the ability to have its level controlled (through an external dimmer that is part of the building or show infrastructure for tungsten fixtures, or through a built in dimmer for LED and arc sources), and controlling the level of different fixtures to create a balanced visual picture on stage is a key part of the job of lighting a performance, it will rarely, probably never, be the case that all of the lights on at a given moment will be running at full power.

Indeed, the electrical installations in most theatres are designed with this in mind, using an approach called 'diversity': turn on all of the connected lights at the same time in any theatre in the world and the main circuit breaker would trip and you'd be left with no light at all!

In addition, performance lighting rigs are for the most part used only during shows, plus a little extra time during rehearsals when a show is first being created. For a typical theatre show, the lighting rig may only actually be in use for two to three hours a day.



Taken together, several studies (including a comprehensive one carried out for the Seattle Rep in America and a broader one carried out for the Mayor of London's Office) have shown that performance lighting typically accounts for just 3-5% of a theatre building's total power consumption.



Power use by performance lighting moment by moment during one performance of The Children's Hour

For one example show (*The Children's Hour*, which ran at the Comedy Theatre in London during 2011), the key figures for show lighting were:

Total connected load (all tungsten):	170kW					
Actual peak load during show:	52.3kW so 31% of connected load - and this just for the curtain calls, often a show's brightest state!					
Show running time:	2hr45min					
Hypothetical power consumption, all lig	ghts on at full power for entire show: 467.5kWh (170*2.75)					
Actual power consumption:	75.5kWh so 16% of the possible power use					

As shows have adopted newer, more efficient lighting technologies as suitable products have become available, the balance of these figures has shifted. A more recent study focused on the current production of *Les Misérables*, playing at the Sondheim Theatre in London. The lighting rig for this production has evolved over its ten year life. The graph below shows how adopting new technology has progressively reduced the show lighting's power use.





Power use by lighting during a performance of Les Misérables, showing how the power use has fallen as the rig has adopted new technology over time. Each coloured line is a different generation of the show; the very lowest shows a hypothetical future version removing arc fixtures entirely.

For the production currently playing at the Sondheim Theatre in London, the corresponding figures are:

Total connected load (all tungsten): Actual peak load during show:	100kW (mix of tungsten, arc, LED) 32kW so 32% of connected load - again just for the curtain calls, often a show's brightest state!					
Show running time:	3hrs					
Hypothetical power consumption, all lig	hts on at full power for entire show: 300kWh (100*2.75)					
Actual power consumption:	89.3kWh so 29% of the possible power use					

Making a direct comparison between these two shows is impossible - they are quite different productions in quite different styles - but note on *Les* Mis how the power required to produce the same lighting has fallen over time as the rig has been updated with new technology (from 124kWh before 2018 to 89kWh now), and in both show how the total power used for one performance is much smaller than would be consumed if all of the lights were just turned on at full.

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As a point of comparison, it is worth keeping in mind that if, instead of coming to watch *Les Mis*, the audience stayed at home and watched television, two or three people per TV, the power required to power all those television sets would be greater than that required to run the show's lighting. Or, at 2020 electricity prices, that the lighting for *Les Mis* would cost just £13 per performance in power costs.

In short, while we should always be seeking to use power more efficiently with the goal, ultimately, of using less power, entertainment lighting has always been a relatively light user of power, and has steadily been reducing its power usage over time as and when suitable new technology has become available and productions have been able to afford to adopt it - without requiring legilsation to force it to do so. It is important to consider not just the efficiency of a single lighting fixture, but the overall usage patterns of those fixtures together. And then beyond that, to consider any environmental impact more widely than just power used.

9. WIDER ENVIRONMENTAL CONSIDERATIONS

Light output per watt of power provides one measure of efficiency, of course, but it does not take into account the wider environmental picture of existing, often long-serving, entertainment lighting equipment. Though not as efficient in terms of power use as the latest products, as we have seen above, even older entertainment lighting equipment is generally not a big power user because of its usage patterns.

Such equipment is also efficient in a broader sense: a product has been made, and gives good service - often for decades. In doing so it does not become scrap waste, and does not require the use of energy and materials to build and ship a replacement. The fixture is easy to maintain, even by staff without any specialist expertise in electronics. It is relatively cheap to keep running: clean it, service it occasionally, replace the bulb on the rare occasions it blows (such fixtures enjoy long lamp life because they are often used dimmed, and are usually faded slowly up from off rather than just being switched on to full - both actions dramatically reduce the shock on filament bulbs and so prolong their life).

In some cases theatres happily continue to use lighting fixtures that are 30, 40, even 50 years old. Where they have upgraded, older fixtures have often been handed down to serve smaller theatres with lower budgets - they still have not become waste.

Mandating higher efficiency products disrupts all of this.

If a theatre using a long-serving rig of tungsten lights were to suddenly discover that their light sources were outlawed and so unavailable, those lighting fixtures would become obsolete, and so scrap - creating more waste material. Notionally more 'efficient' replacement products, if available, would have to be created and shipped to the theatre, consuming more resources in the process. Such equipment would be very expensive compared to the occasional cost of replacing a light bulb. It may be more expensive still to actually bring into use because it might also require the replacement of the



traditional lighting infrastructure of external dimming with an entirely new control infrastructure, creating more scrap waste as part of the process.

In addition, it will be very hard to recoup the high purchase costs of this equipment from savings in power costs. By moving to more efficient equipment over time, *Les Mis* has reduced the electricity cost of the lighting for one performance from about £18 to about £13 (at 2020 power prices), a saving of just £2080 a year. Not nothing - but less than the price of just one fixture out of the hundreds the production uses.

A study into a season of shows at Seattle Rep in 2011-2012 monitored how much power their rig of traditional lighting fixtures actually used during a performance of each of the season's shows.



Power consumption during the performances of six plays at Seattle Rep. Each coloured line represents a different show.

At the time, the conclusion was, again, that the savings in power costs would not outweigh the additional costs of switching to LED equipment. There was also a suspicion that the energy savings from any new LED fixtures would not outweigh the additional energy consumed by building and shipping these new fixtures, over the working lifetime of those new fixtures. There were still good reasons for choosing LED fixtures, particularly when equipping a new venue or show from scratch, in pursuit of the greatest efficiency. When replacing existing fixtures the balance was harder to establish.

In this sector, it is likely that changing the regulations to only allow notionally more efficient light sources will actually cause overall net harm to the environment - a position supported by the entertainment industry environmental charity <u>Julie's Bicycle</u> during discussions about Ecodesign in 2018-2020.

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10. POTENTIAL IMPACT ON VENUES AND PRODUCTIONS

The impact of imposing a very simplistic 120lm/W requirement will be different for different types of users.

Smaller Venues

Smaller venues - village halls, schools, small theatres - provide the backbone of the entire entertainment industry in the UK. It is where people discover their love of the arts and creating events, and start to learn their skills, backstage and onstage. There are hundreds, perhaps thousands, of such venues across the UK.

An informal survey of mid-scale UK venues in 2018 identified that 74% of the entertainment lighting equipment in use was more than 25 years old, but still serving its purpose, able to be maintained by those using the venue and with the relatively low running costs of just a new light bulb every now and again - an occasional £15 or so per fixture. New fixtures have traditionally been procured second hand or as hand-me-downs from larger theatres upgrading their equipment.

Should the supply of the light source (bulbs) these fixtures rely on end, replacing each fixture with new LED fixtures would cost anything from \pounds 500 to \pounds 2500 per fixture depending on type and quality, and would also require a new lighting infrastructure to accommodate LED technology - an additional cost in the region of \pounds 10,000 for a small venue, and a total cost of potentially millions of Pounds across all venues. The new technology would also be harder for the venue's staff to maintain in the long term, and would be likely to have a shorter working life because of the electronics these products contain.

Larger Venues

Larger venues may already be in the process of upgrading their fixtures to new LED fixtures, although in many cases that will have been disrupted by the Coronavirus pandemic over the last few years and may continue to be disrupted as it will take time for finances to recover from that. The National Theatre, for example, is some way through a multi-year, multi-million pound project to upgrade all of the entertainment lighting equipment across its three venues to efficient, LED fixtures. But even here, budget limitations means that this change happens over years, not all at once.

Here the danger is that you ideally would like consistency: to be able to buy some lights now, and to buy matching lights later either to increase your stock or as replacements for existing units. Imposing what would in effect be a ban on the continuing sale of existing fixtures would disrupt this. And if no suitable products meeting the proposed standards are available at all, as seems likely, then it would not be possible even to add 'better' fixtures - there would be nothing suitable available to buy.

Rental Companies

Productions with a defined but limited life (for example, concert tours) or where it is not known how long the production will run (for example, a new musical) will not usually purchase lighting equipment, but will instead rent it from specialist entertainment lighting rental companies.



Rental companies own large stocks of existing lighting fixtures. Pre-LED fixutres (tungsten, arc, and in the case of floodlights used in the film industry to light green-screens, fluorescent) rely on an ongoing supply of replacement bulbs to allow them to continue to function. In this case the bulb is what would have to meet the efficiency standard - and none currently do. Were these bulbs to become unavailable then as stocks of these bulbs dried up these lighting fixtures would become prematurely obsolete - in effect, become scrap. This mass of scrap, and the energy required to create and ship replacement fixtures, would likely dramatically outweigh any power savings achieved by moving to LED light sources.

Plus, again, while rental companies are already transitioning to LED products, the pace of this is ultimately governed by the money available. It is a transition that has been happening at a faster pace than many expected, but it is likely to slow now because of the financial impact of the pandemic both on the companies directly and on the organisations they supply to. Even where companies want to upgrade, they simply can't afford to.

As a real-world example, <u>White Light</u>, who are a lighting supplier servicing all areas of the entertainment industry with an annual turnover in normal times of around £40million, note that as of January 2022:

- they owned 4500 automated moving lights.
- of those lights, 55% are LED, 15% tungsten, 30% arc (compared to 40% LED in 2019-2020).
- to replace all of the arc units immediately, as might be required were lamps to become unavailable, would cost approximately £6million.
- £6million is approximately two years of the company's entire capex budget (which must cover all equipment, not just moving lights and non-moving lights would also be impacted).
- currently as new equipment is purchased, older equipment is resold second hand. That market would no longer exist in the UK.

If energy saving/increased efficiency per fixture is the overwhelming primary goal, then existing users may need financial support to allow them to transition to compliant new lighting tools (should they become available). Such support could emulate the schemes put in place to help radio microphone owners purchase new equipment as spectrum sales rendered older wireless products obsolete.

However, it would surely be more effective overall to just allow people to continue to use the fixtures they have, with the relatively low use of power they make, for as long as they can.

It would seem more sensible from an overall environmental perspective to allow equipment to continue to be used to the end of its natural working life and then replaced by more efficient alternatives, rather than forcing equipment into premature obsolescence.



11. A WILL, BUT POSSIBLY NO WAY

It should be re-iterated that this is all moot at the moment anyway since **no** entertainment lighting fixtures or light sources that meet the proposed standard are currently available, or are likely to be available in at least the next five years.

Specialist entertainment lighting fixtures in many cases still cannot meet the 85lm/W standard in the current GB/EU regulation, which is why exemptions were created to accommodate the scientific limitations involved in designing equipment of this type.

The worst-case scenario presented by the proposed new GB regulation is that:

- Existing tungsten lamps are not permitted. All existing tungsten lighting fixtures become obsolete as supplies of these lamps are exhausted (estimated at a one year timeframe).
- Existing arc lamps are not permitted. All existing fixtures using these lamps become obsolete as supplies of these lamps are exhausted.
- No suitable fixtures are available as replacements, since no current LED fixtures or LED fixtures foreseen in the next five year period are able to meet these requirements.
- The entertainment lighting industry in the UK therefore no longer has the tools available to carry out its work. Productions and events relying on entertainment lighting either suffer as a result or, where they can, re-locate outside the UK.
- Lighting practitioners in other countries, still with ready access to lighting tools, take over the mantle as leaders in the field from UK practitioners.

This sounds like a doomsday scenario. But it is actually alarmingly possible.

12. POSSIBLE FUTURE EXEMPTIONS

The entertainment lighting industry - users and manufacturers - believes that there remains a clear need for the specialist nature of entertainment lighting fixtures to be recognised in any future lighting regulations in the UK.

The entertainment lighting industry has demonstrated time and time again that it is willing, able, indeed keen to adopt the latest lighting tools, from candles, to gas, to electricity, tungsten to LED, as suitable tools using those technologies become available.

The move to LED fixtures is happening at a rapid pace where budgets allow. This change will continue to spread through all levels of entertainment lighting, particularly as the supply of tungsten light sources comes to a natural end.



However, it must be noted once again that the coronavirus pandemic of the last two years has had a very serious impact on entertainment venues and producers, with venues closed and live shows cancelled for much of that period. Even venues and organisations that were planning change prepandemic may not now have the finances available to do so in the near to midterm. They need time to re-build their finances, and they need to be able to use their existing equipment to help them do so.

And when they come to do so - they will only be able to do so if suitable equipment is available,. To re-iterate, **no specialist entertainment lighting equipment is available now, or is foreseen in at least the next five years, that will be able to meet the proposed 120lm/W requirement.** As outlined above, the absolute worst case scenario is that existing equipment is forced into obsolescence, but no suitable equipment is available to replace it regardless of price.

The current version of the regulations provides suitable protection for key entertainment lighting tools. The relevant sections could be maintained in any new regulation, including the need to preserve entertainment lighting fixtures' ability to respond instantly to commands to change output rather than requiring a very low power 'standby' mode.

While maintaining this status quo would do nothing new to encourage users to migrate to new technologies, this migration is happening naturally anyway as older light sources become unavailable through no longer being manufactured. Trying to force this change at a faster rate will achieve nothing or actually cause harm if organisations can't afford to change at that pace or if there is no suitable equipment to change to.

However, the sections of the current regulation that impact entertainment lighting are quite disparate and complex. A simplification through re-ordering and re-arrangement would help make things clearer.

It would also be possible to simplify the regulations more dramatically, by providing an exemption based on use in a particular sector (such as 'lighting for live or recorded entertainment events'), or for equipment designed specifically for a particular sector. Suitable standards for identifying such equipment already exist - for example, EN60598-1 and EN 60598-2-17: Luminaires for Stage Lighting, Television and Film Studios (Outdoor and Indoor), or the older British standard that preceded the EU versions.

Defining an exemption in this way would not only simplify the regulation, but also 'future proof' it against new technologies as they find use in entertainment industry lighting applications - as is happening currently with laser light sources. This was the approach we suggested to the EU in 2018-2020, but which they rejected in favour of their item-by-item approach.

There may be a concern that such exemptions would reduce the drive by the sector to adopt new technologies. But this sector has already been doing that without being forced to do so by legislation. There is no reason for it to stop, and other driving forces (traditional light sources going out of production) ensure it cannot stop.



13. DIVERGENCE WITH REGULATION IN OTHER COUNTRIES

It is worth noting finally that outside a few specialists with particular niche product ranges, there are no mainstream entertainment lighting equipment manufacturers now based in the UK. Key products come from manufacturers in the US, across Europe, and of course in China.

Should UK regulations diverge too far from regulations in those manufacturer's other key markets, especially if becoming more onerous, there is a danger that manufacturers will just decide it is not worth the effort of selling their products in the UK particularly (in the case of European manufacturers) given that complexity has already increased because of Brexit. This is already being seen in the field of cars, where some models are no longer available in the UK despite still being sold elsewhere. In the EU the indication is that the next round of Ecodesign will concentrate on areas other than increased efficiency as achieving further meaningful gains becomes challenging and expensive.

The UK has a unique talent and world-renowned ability in the field of entertainment lighting design. But that ability needs access to the tools of the trade, and could easily be disrupted should those tools no longer be available.

14. SUMMARY AND CONCLUSION

Entertainment lighting is a serious business. UK practitioners are leaders in the field, in demand around the world. Their work helps to create remarkable productions, many of which are then seen around the world to great artistic acclaim and commercial success. Lighting is a critical component of the cultural sector, which is a key industry within the UK.

Entertainment lighting relies on specialist lighting tools. Those tools are increasingly efficient, and are used in efficient ways.

Those tools cannot and likely will not be able to meet simple lumen/Watt efficiency measurements that are really designed for entirely different types of light sources in entirely different lighting applications and take no account of the specialist nature of entertainment lighting fixtures in terms of their beam characteristics and overall light quality.

Light quality is a key consideration. It is actually one which should be more widely factored in to any conversation about light - quality of light is a quality of life issue - but tends not to be. It is easy for the casual observer fail to understand why a shift to more 'efficient' light has reduced the quality and comfort of their environment. Entertainment lighting professionals do understand the critical importance of light quality and the importance of defending and preserving it.

We would therefore ask that due consideration be given to providing suitable protection for specialist entertainment lighting fixtures within any future UK lighting regulation.

We thank you for your time, and of course remain available to you to answer questions you may have or to provide further information you may require.



APPENDIX A: SAMPLE LM/W FIGURES FOR ENTERTAINMENT FIXTURES

						COMPLETE FIXTURE			LIGHT SOURCE ONLY		
Mfr	Model	Source	Туре	CRI	Col Chg	Output, Im	Power, W	Eff, Im/W	Output, Im	Power, W	Eff, Im/W
Ayrton	Diablo S	LED	White	70	CMY	19000	550	34.5	26500	420	63
	Diablo TC	LED	White	90	CMY	14000	550	25.4	20500	420	48.8
	Huracan Profile	LED	White	70	CMY	53000	1600	33.1	75000	1000	75
	Magicburst	LED	White- Strobe	85	-	240000	1400	171			
Clay Paky	Axcor Profile 600	LED	White	70	СМҮ	18100	800	22.6	28000	500	56
	Axcor Profile 600 HC	LED	White	95	CMY	14300	800	17.9	16500	500	33
	Aleda B-eye K25	LED	RGBW		RGB W	15000	1250	12.0	23000	1000	23
	Xtylos	Laser	RGB		RGB	3000	400	7.5	4000	180	22
ETC	Source Four Spot	Tungs	Tungs	100	-	8500	750	11.3	18975	750	25
	Source Four Spot	Tungs	Tungs	100	-	7489	575	13.0	14900	575	26
	Source 4WRD Spot Standard	LED	White	80	-	11430	175	65.3			
	Source 4WRD Spot Gallery	LED	White	90	-	9716	175	55.5			
	Source 4WRD Spot Colour	LED	Col Mix	83	RGB A	4881	144	33.9			
	Source Four Lustr2 x7	LED	Col Mix	90	7 col mix	5882	160	36.8			
	Source Four Lustr3 x8	LED	Col Mix	98	8 col mix	10889	305	35.7	17976	274	65
Martin	Viper Performance	Arc	White	85	СМҮ	26000	1186	21.9	85000	1000	85
	Viper Wash	Arc	White	85	CMY	33000	1186	27.8	85000	1000	85
	Encore Perf CLD	LED	White	80	CMY	11600	532	21.8	39400	468	84
	Mac Ultra Performance	LED	White	83	CMY	46500	1380	33.7	90000	1150	78
	Mac Ultra Wash	LED	White	83	CMY	63500	1380	46.0	90000	1150	78
	Mac Aura PXL Wash	LED	Col Mix	73	RGB W	10500	500	21.0	19000	419	45

General Notes:

- Figures sourced from manufacturers directly and from published data. Some decimal values rounded for clarity. Blank cells means data could not be ascertained. We believe this a representative, though not exhaustive, sample of fixtures.

- All but the ETC fixtures listed are moving lights. Fixture power quoted is with the fixture static; power consumption will vary slightly with the light moving or built-in effects active.

- CMY indicates subtractive colour mixing using motorised cyan-magenta-yellow glass flags; some include additional colour flags.

- RGB indicates additive colour mixing using red-green-blue LEDs. A is additional amber source, W additional white source.

- CRI for colour mixing fixtures will vary with mixed colour. Maximum achievable CRI values are shown.

General Observations:

- Wash fixtures generally more efficient than spot fixtures for complete fixture output because fewer lenses so less lens loss.

- Higher CRI fixtures generally less efficient than lower CRI fixtures.

- Whether measuring light source output or fixture output, all fall some way short of the proposed standards.



APPENDIX B: THOUGHTS FROM FIXTURE MANUFACTURERS ON THE CHALLENGES OF INCREASING FIXTURE EFFICIENCY

These are selected comments from a variety of manufacturers and suppliers, on the challenges of increasing the efficiency of their products. Since all are making similar points we haven't felt it necessary to identify particular manufacturers here.

A:

We do not see any of our current technology providers managing to get to anything beyond this 60/70 lm/Watt barrier. Lens technology, coatings and LED output are all close to the physical limits of production. Thermal limits on cooling mean that LED engines are probably at 90% of their theoretical maximum using air as the cooling medium (most performance spaces are in air and not under water!) and lens technology is a fully developed science. Discussions with optical teams leads me to believe we are capable of perhaps a further 5% of transmission efficacy but this would be massively more expensive for the modest gain.

Disruptive lighting technology is rare. In over 200 years we have had 4. Hot filament lamps (the light bulb), gas excited tubes (the fluorescent tube), arc lamps (street lights and film lights) and finally solid state sources (LED). I think the possibility of a future technology doubling theatrical efficiency of lighting instruments is unlikely in the short or medium term.

B:

- General lighting is allowed to spread the light "everywhere", whereas we have to e.g. frame a stage or artist (for projection fixtures).
- To enhance the optical efficiency our light sources need to be small and powerful (high flux density), so we can shape and direct the light efficiently (etendue limitations) inside the optical system. If the light source is not compact, the entire product will grow in size and weight, which has many negative impacts.
- The compact light sources and higher currents also increases the operating temperature of the LED (junction temperature) which further reduces the Im/W.
- The systems are further challenged by having to both go narrow and wide this sets additional requirements to the light engine and puts a penalty on the Im/W.
- Although we improve optical efficiency as much as we can by using compact light sources, not all light from the light source can be captured.
- In projection fixtures, the light has to travel through multiple layers of lenses (e.g. 13 lenses) and there is a loss at each surface even though we use antireflective coatings.
- Regardless of how it is measured, we do not see any technologies available within a predictable future that can lift the efficacy for stage lighting fixtures to levels of 120 lm/W or a future 140 lm/W.

So in short, it is not possible to obtain same efficacy for directional and projection systems as opposed to general lighting fixtures with simple flood optics or naked sources.

C:

In general, light sources for moving heads are above 500W electrical consumption and 60-80lm/W efficiency in white, dropping down to 40lm/W in case of a 5 color source. And this is the light source. Then take 20-60% efficiency in gate and optical system (depending on the zoom value, very low for spot below 10°), and you immediately see that our moving heads are far away from 120lm/W. Future developments will never fill this gap in next 3-5 years.



APPENDIX C: PRODUCTS SHOWN AT THE NATIONAL THEATRE / BEIS ENTERTAINMENT LIGHTING WORKSHOP

The products shown may change slightly on the day, but are expected to include:

Tungsten:

ETC Source Four spotlight - the industry-standard tungsten lighting fixture. Robert Juliat spotlights - larger, higher output fixtures for bigger venues.

Robert Juliat 1kW and 5kW Fresnels - wash fixtures of various light outputs.

Par64 - a sealed beam wash light - low cost so in very wide use. Birdie - a tiny lighting fixture, great for hiding in scenery, but which uses the MR16 low voltage bulb which is not permitted under Ecodesign and so is now hard to find.

Vari-Lite VL1000 - a tungsten moving spotlight with mechanical colour changing. Vari-Lite VL550 - a tungsten moving washlight with mechanical colour changing.

Arc:

Martin Mac Viper Pofile and Wash DX - arc (MSR) moving spot and washlights.

LED - White Source:

Martin Mac Encore Spot and Wash WRM - warm white source moving spot and washlights

ETC Source 4WRD - drop in replacement LED source for existing tungsten Source Four fixtures, in Standard (CRI 80) and Gallery (CRI 90) white versions.

LED - Additive Colour Mixing:

Product to be confirmed - a low-end LED fixture with poor RGB colour mixing.

Arri SkyPanel: A large-surface washlight used in film and TV production.

Martin Mac Aura - an open-face moving light with RGBA colour mixing. Vari-Lite VL800 ProPar - a Par can replacement with RGBW colour mixing. GLP X4 Bar - a linear moving washlight with RGBW colour mixing.

ETC Source 4WRD Colour - drop in replacement LED source for existing tungsten Source Four fixtures, in its colour mixing (RGBA) version.

ETC Source Four Lusrtr2 spot - the highest light quality additive colour mixing fixture until this year, reponsible for many entertainment lighting designers finally accepting LED sources. 7 colour additive colour system (red, green, blue, indigo, cyan, amber, lime).

ETC Source Four Lustr3 spot - the latest member of this family of lights, which now adds an additional deep red LED to give an eight colour system to quite remarkable effect.

Control was using an ETC Eos specialist entertainment lighting control system.



APPENDIX D: THOSE PRESENT AT THE NATIONAL THEATRE / BEIS ENTERTAINMENT LIGHTING WORKSHOP

The participants present at the National Theatre entertainment lighting workshop on Thursday February 10th 2022 were:

Rob Halliday (workshop lead / document author)

Rob is a lighting designer, lighting programmer and technical writer. He has worked on shows around the world for more than thirty years, his lighting seen on productions such as the acclaimed dance show *Tree of Codes* (with Wayne McGregor, Olafur Eliasson and Jamie xx) and the multimedia spectacular *Guidizio Universale*, and supporting other designers on productions including *Les Misérables*, *Billy Elliot* and many others. He writes about lighting and other entertainment technology for a range of industry publications. He has been closely involved with entertainment lighting and Ecodesign since 2018.

Contact: rob@robhalliday.com.

Adam Bennette

Adam has many decades of experience in professional entertainment lighting, including the design and manufacture of luminaires and lighting control systems for use in the world's most prestigious theatres, studios, theme parks and opera houses. He is the author of eight patents relating to the design and control of colour-mixing lighting fixtures and the designer of a number of succesful lighting control products with significant worldwide sales. He has delivered lectures in Europe and the USA on the topics of colour control, power supply harmonics, colour perception, theatrical electrical infrastructure and the use of International Standards for compliance.

Adam is the representative for PLASA at the British Standards Institute (BSI) for Low Frequency EMC (committee GEL210/11) and Luminaires (CPL34); during this tenure he has been actively engaged in setting compliance policies for harmonics produced by professional lighting equipment and other topics. He is the author of the industry guidance document *Recommended practice for DMX512* which has been in use for more than 20 years, is still current and has been translated into more than ten languages.

He has been employed as Technical Director of Electronic Theatre Controls Ltd for the last 27 years.

Robbie Butler

Originally from Ireland and now based in the UK, Robbie is one of only a handful honorary life members of the Association for Lighting Production and Design (ALPD). A graduate of the Royal Conservatoire of Scotland, he has received three Off West End award nominations for Best Lighting Design and was the winner of the 2015 ETC Award. His recent work includes *Young Frankenstein The Musical* (English Theatre Frankfurt); *The Happy Tragedy of Being Woke* (Complicité - Edinburgh International Festival); *Down and Out: Live* (La Generale, Paris), and the operas *The Angel Esmeralda* (Guildhall School); *Isabeau* (Opera Holland Park and *Dialogues Des Carmelites* (Guildhall School). Robbie co-led the 2018 Save Stage Lighting Campaign including instigating the high profile projections onto theatre buildings to highlight the risks the proposed Ecodesign regulations posed to entertainment lighting.



Paule Constable

Paule is a UK-based lighting designer working in Dance, Drama and Opera across the globe. She has won awards for her lighting for *War Horse*, *Curious Incident Of The Dog In The Night*, *Les Misérables*, *Ocean At The End Of The Lane, Follies* and others. She is an Associate of the National Theatre and of Matthew Bourne's New Adventures, a Royal Society Royal Designer for Industry, a founder member of Freelancers Make Theatre Work and a dedicated campaigner for sustainable theatre.

Matt Drury

Trained at the National Youth Theatre of Great Britain and the Bristol Old Vic Theatre School, Matt has been working in the Lighting profession for over 30 years, in a variety of roles as a Lighting technician, in both a regional and freelance capacity, a Lighting Designer for over 70 professional theatre productions & corporate events and a Lighting Tutor at both RADA and LAMDA, as well as previously being LAMDA's Technical Director. He is a member of the ABTT and ALPD and is delighted to be part of the ALPD Wellbeing group. He was formerly Head of Lighting at the Royal Court Theatre and is currently the Head of Lighting at the National Theatre.

Peter Heath

Peter took the role of MD at PLASA (the Professional Lighting and Sound Association) in 2016, bringing with him over 30 years' experience in the industry; previously he worked for a Japanese musical instrument manufacturer, running their Pro Audio/Video division across Europe.

Along with the PLASA team, he works hard to support PLASA members, keeping them updated on skills and technical matters as well as helping them market their products and services through media and trade events.

During the pandemic Peter was one of founders of the We Make Events campaign, helping to support and make the case to Government for an industry that was almost entirely shut down. We Make Events now has over 40 countries across the globe taking part in its activities.



APPENDIX E: BACKGROUND INFORMATION ON ECODESIGN, ENTERTAINMENT LIGHTING AND POWER USAGE

Ecodesign:

(note that ALPD is a new name adopted in 2021; the organisation was previously known as the Association of Lighting Designers (ALD), with those initials shown below)

ALD Response to the EU, 25th January 2018: <u>https://www.ald.org.uk/sites/default/files/resources/ResponsetoEUProposalfromthe</u> <u>ALD.pdf</u>

Additional Comments In Response to the EU from ALD Members: <u>https://www.ald.org.uk/sites/default/files/resources/ALDResponsetoEUProposalAdd</u> <u>itionalComments.pdf</u>

ALD Follow-Up Response to the EU, 7th May 2018: https://www.ald.org.uk/resources/ald-follow-up-response-to-eu-proposal

ALD Primer on the Proposed 2020 EU Lighting Regulations: <u>https://www.ald.org.uk/resources/the-proposed-2020-eu-lighting-regulations-a-primer</u>

Julie's Bicycle Response to the EU regarding the Environmental Impact of the Proposed 2020 EU Lighting Regulations: https://www.juliesbicycle.com/News/eu-stage-lighting

Entertainment Lighting / Production and Power Use:

Mayor of London's Green Theatre Study, September 2008: <u>https://www.london.gov.uk/sites/default/files/green_theatre_summary.pdf</u>

Seattle Rep Performance Lighting Energy Use Study 2011-2012: <u>http://www.lightingandsoundamerica.com/reprint/EnvironmentStageLight.pdf</u>

Les Misérables Performance Lighting Energy Use Study 2020: <u>https://edition.pagesuite-</u> professional.co.uk/html5/reader/production/default.aspx?pnum=65&edid=fc5997aa-e797-<u>4432-9d66-2967c8049904&isshared=true</u>

Theatre Green Book: <u>https://theatregreenbook.com</u>

Other Information Sources Referenced By This Document:

HM Government Industrial Strategy Creative Industries Sector Deal 2018; House of Lords Select Committee on Communications Skills for theatre: developing the pipeline of talent 2017; Offstage Workforce Review of the Theatre and Performing Arts Sector for UK Theatre and the Society of London Theatre 2017; PEARLE draft response to the EU 2018; research into The Future of the UK Entertainment Sector by NymanLibsonPaul; Wish You Were Here 2017 - annual report by UK Music; Business and Events Partnership; background information from the National Theatre, PLASA, White Light Ltd, We Make Events, Freelancers Make Theatre Work, other lighting industry suppliers.



APPENDIX F: FURTHER READING ON ENTERTAINMENT LIGHTING

Periodicals & Online Publications:

Light+Sound International Magazine: https://www.lsionline.com/magazine/digital

Lighting & Sound America Magazine: <u>http://www.lightingandsoundamerica.com</u>

Live Design Online: <u>https://www.livedesignonline.com</u>

PLSN: https://plsn.com

ALPD Focus Magazine: <u>https://www.thealpd.org.uk</u>

Books:

Fraser, Neil: Stage Lighting Design: Second Edition
Hays, David: Light On The Subject
Halliday, Rob: Entertainment In Production, vols 1 and 2
Keller, Max: Light Fantastic: The Art and Design of Stage Lighting
McCandless, Stanley: A Method of Lighting the Stage
Moody, James: Concert Lighting: Techniques, Art and Business
Moran, Nick: Performance Lighting Design
Moran, Nick: The RIght Light - Interviews with Contemporary Lighting Designers
Mort, Skip: Stage Lighting - The Technician's Guide
Pilbrow, Richard: Stage Lighting Design - The Art, The Craft, The Life
Pilbrow, Richard: A Theatre Project
Reid, Francis: The Stage Lighting Handbook

Collections of Historic Information:

Theatrecrafts - Entertainment Technology, Resources & History: <u>https://www.theatrecrafts.com/pages/home/archive/</u>

The Lighting Archive: https://thelightingarchive.org

New Technologies: ETC Advance Research Group on Colour and LEDs: <u>https://www.youtube.com/watch?v=kKx545RPWNA</u>

Kino-Flo on Colour and LEDs: <u>https://www.youtube.com/watch?v=yehHf83oUuc</u>





ALPD

The Association for Lighting Production and Design is the body representing all those who work in or are interested in the creation of lighting, video and projection for live performance and events. It is an association that welcomes lighting and video designers, technicians and programmers across the full range of performance lighting disciplines. Formed in 1961, the Association today has a membership of just under 1,000 ranging from internationally recognised names at the top of the industry, through to students and the emerging practitioners of tomorrow. https://www.thealpd.org.uk



PLASA

PLASA is the lead international membership body for those who supply technologies and services to the event and entertainment industries. The organisation supports its members in the areas of business, technical, safety and regulatory issues. Its commercial division produces the industry publications L+Si and L&SA, while its PLASA Show in London and regional Focus events provide businesses with the opportunity to showcase their technology and services.

https://www.plasa.org

CONTACT

Rob Halliday continues to act as a central point of contact for Entertainment Lighting and Ecodesign: rob@robhalliday.com 07973 319793

The ALPD can be contacted at office@alpd.org.uk PLASA can be contacted at info@plasa.org

Lighting Design Credits:

p3: Red & Harry Potter and the Cursed Child (Neil Austin), Equus & Les Misérables (David Hersey), An Inspector Calls (Rick Fisher), Six (Tim Deiling), War Horse (Paule Constable), The Phantom of the Opera (Andrew Bridge). p4: London 2012 & Adele (Patrick Woodroffe), Sam Smith & Stormzy (Tim Routledge),

Coldplay (Paul Normandale), Strictly Come Dancing (David Bishop).

The Mandalorian and The Crown - various Directors of Photography.

[ENDS]

