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Towards An Era Of Eco-Friendly Theatre Lighting Equipment: An Imperative For A Transition From Incandescence To Light-Emitting-Diodes

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ABSTRACT
The heat and other dangerous consequences that emenate from the use of incandescent and florescent lamps in theatre lighting instruments during performances, not only posse adverse effects on performers and on performances, but also pose serious threats to the eco-system. On the other hand, the invention of LEDs – Light Emitting Diodes (an eco-friendly type of electrical light bulb) provides a better alternative for an eco-friendly lighting system and some countries have even proscribed the use of incandescent lamps; yet, many theatre lighting equipments are still being manufactured with incandescent lamps and churned-out into the market; hence, in a bid to promote the use of environmentally friendly lighting system that would discontinue the adverse effects posed by incandescent and florescent lamps, this study situates its argument within the context of educational environmentalism - offering knowledge that urges to protect humans and their environment. Through a blend of scholarly and analytical framework, this study submits that a total transition from the use of incandescent lamps in theatre lighting equipments to the use of Light Emitting Diodes – LEDs lamps should be adopted by the theatre lighting equipment manufacturing countries (like the United Kingdom, China, United States of America, and others) in other to nip the problems generated by incandescent lights in the bud; and protect the theatre artists and the eco-system.

Keywords: Theatre Lighting, Global-warming, Incandescent lamps, LEDs, and Eco-friendliness

INTRODUCTION

Due to environmental hazards caused by the use of incandescent electric lamps, "Environmental activist and former U. S Vice President, Al Gore believes that switching from incandescent light bulb can help save the planet from global warming." (Culled from: http://www.ehow.com/list_6367767_environmetal-effects-incandescent-light-bulbs.html). As a result of the dangers of incandescent lamps on the eco-system, some jurisdictions, such as the European Union, China, Canada and United States, are in the process of phasing out the use of incandescent light bulbs while others, including Colombia, Mexico, Cuba, Argentina, Brazil and Australia, have prohibited them already. (Culled from: https://en.m.wikipedia.org/wiki/incandescent_lamp).

The statement of problem is that, many theatre lighting instruments (with incandescent lamps) such as Fresnel, Parabolic Cans (Parcans), Follow-spots, Ellipsoidal spots, Scoops and Boarder lights are still prevalently in use in Nigerian theatres and perhaps, theatres of some other nations because they are still in circulation; partly because so many people seem to be unaware of the environmental unfriendliness of the incandescent lamps; hence, in a bid to promote environmental friendly ecosystem, to ensure a better world for living beings, this study seeks to critically analyze the dangers of incandescent filament lamps in theatre lighting equipments (and even in homes); hence the imperative for an urgent switch from the use of incandescent filament lamps, to the use of LED (Light Emitting Diode) lamps for theatre lighting and in homes.

Though there are several other types of electrical lamps, the core of this study is limited to a comparative analysis of the features, advantages, and disadvantages of the most commonly used types of lamps in the theatre/homes and a more effective and efficient invention that is a suitable replacement, and how they affect theatre practice and the ecosystem. These lamps are: the incandescent lamps, florescent lamps and the Light Emitting Diodes – LEDs.

This study is significant in the sense that (among other things) it will create awareness on the dangers of incandescent lamps on the artists and the environment; so as to bring about a conscious and deliberate change in the trend of lamps that are manufactured for theatre lighting equipments – that is, from eco-unfriendly lighting equipments to eco-friendly lighting equipments. Factoring the recommendations of this study into plans and policies for disaster risk management in global sustainable development plans will make theatre lighting less hazardous and the eco-system a safe habitat.

The word, "incandescent", according to Oxford Advanced Learner's Dictionary (p.604), means that which gives "out light when heated…" Wikipedia free encyclopedia also defines incandescent light bulb, incandescent lamp or incandescent light globe as "an electric light which produces light with a wire filament heated to a high temperature by electric current passing through it, until it glows." (Culled from https://en.m.wikipedia.org/wiki/incandescent_lamp). On the other hand, Parker, Wolf and Block (p.497), define incandescent filament lamp as "a glass bulb enclosing a tungsten filament that emits light when an electric current is passed through it." According to Gillette (337), "all filaments of stage lighting lamps are made of tungsten wire…". Of all lighting fixtures that use incandescent filaments lamps for lighting, theatre lighting equipment such as 1000watts Par Can 64, Fresnel, Ellipsoidal spotlights, Profile spotlights, 2000watts Follow-spot lights, etc., can be classified among lighting equipment that are most environmentally unfriendly as they consume very high volumes of electrical energy than most others, they generate very high heat intensity (the higher the wattage, the higher the energy consumed/heat generated), and contain elements which posse environmental hazards.

According to Natural Resources Defense Council, USA: after some analysis of the overall impacts of various lighting products were carried-out, it was proved that, though incandescent lights do not contain mercury within the bulb, "they result in the highest level of mercury emissions to the environment"; due to the percentage of coal-fired power plant that is required to produce electricity. (Culled from: http://www.nrdc.org/energy/default.asp). That is to say that: the more the coal fired to generate power, the more the mercury emitted into the environment, and the more hazardous the environment becomes.

Parker, Wolf and Block corroborates with the thrust of this study (which is the imperative for an immediate transition from the use of incandescent lamps to the use of Light Emitting Diode (LEDs) as they aver that:

> We are on the threshold of great change in the light source technology; it would seem that the reign of the old workhorse incandescent lamp is coming to an end. Because of its inefficiency (only 10 percent of energy is turned into light), environmentalists are calling for elimination of incandescent light sources. The thought is that current incandescent could be replaced . . . However, much research is currently being conducted on an even more efficient source of light that does have potential for stage-lighting applications: LED, or light emitting diode. (p.496). [Emphasis mine].

The Theoretical Framework:

The thrust of this study is based on an environmental theory which is tagged: "educational environmentalism" (Culled from: https://en.m.wikibooks.org/wiki/Environmental_theory_and_collection_of_ideas/Evironmentalism_and_ethical_theory). The theory states that: in order to make this world better, people should be more ethically and environmentally conscious. The inclination to save the entire living world by making it more environmentally friendly, presupposes intelligence, and its motivation is similar to the motivation for making a human community survive well, and therefore humans should solve their environmental problems.

The desire for survival is an instinct, and intelligence deems it probable that the survival of our genes as a goal depends on the survival of some other parts of earthly life. This is why it seems to be logical that humans make such decisions that increase the probability of life on earth persisting longer. This theory is called "ethical environmentalism" if someone chooses to protect the environment by decision in his/her power. It can be called "political environmentalism" if a group makes and environmental agreement which influences the rule of evolutionary struggle. While it can be called "**educational environmentalism**", if someone offers knowledge that urges to protect the environment. (Culled from: https://en.m.wikibooks.org/wiki/Environmental_theory_and_collection_of_ideas/Evironmentalism_and_ethical_theory).

In a bid to offer a scholastic and analytical discourse on the imperative for a transition from the use of incandescent lights to LEDs; geared towards protecting the ecosystem, this study shall among other things, establish why light/lighting is needed in the theatre (in the first place), a brief history on the invention of incandescent electric lamps, types of electric lamps and their components, the dangers of incandescent lamps to the ecosystem, and a comparative analysis of the energy efficiency and environmental impacts of incandescent lamps, fluorescent lamps and the LED lamps.

The Importance of Light/Lighting in the Theatre:

The theatre can simple be defined as a place of seeing. (Okeke 100). This definition therefore presupposes that the primary aim of people going to the theatre is to see. This therefore means that illumination (be it artificial or natural) is a necessity for theatre to have meaning; and it is only light that gives Illumination. Therefore, light/lighting (natural and/or artificial) can be seen as inalienable prerequisite of theatre

functionality. Furthermore, stage lighting is described as:

> …a remarkable part of modern theatre. Remarkable because, although theatrical productions have been presented for many thousands of years, the new ability to accurately and sensitively control light has led to stage lighting's emergence as an ever more significant element in the creation of theatre. (Pilbrow 1997, in Oni 76)

Alluding to the importance of light/lighting in the theatre, Stanton and Banham (1996, in Oni 76), state that:

> Stage lighting, particularly in the 100 years since the first use of electricity in the theatre, has had a profound effect upon staging, scenery, style of production and acting, and even upon the shape of theatre building itself.

To further affirm the important role of light/lighting in the theatre, Nwadigwe (81), states that lighting is an integral part of theatre which has been applied in one form or the other in theatrical productions to enhance aesthetic appreciation and communication.

Due to the nature of theatre as an art form for communication, the need for light/lighting may go beyond mere illumination. According to Asuquo (249 - 252), the functions of stage light/lighting include: provision of visibility, revelation of shapes and forms, directing focus and for creating composition. In addition, Henning Nelms (244), avers that stage lighting can be used to set the style of a production. Francis Hodge (248), states that light is one of the "strongest allies" in creating mood in play productions. While Ommanney and Schanker opine that: "lighting is probably the … most versatile source of special effects for accomplishing such feats as changing the stage into a blazing inferno, creating fog, mist, etc"; as may be required . The above listed points are basically the reasons theatrical productions need light/lightings.

Types of Electric Lamps

A lamp is a replaceable component of light fixture or lighting instrument that produces light from electricity. Lamps usually have a base made of ceramic, metal, glass or plastic, which secures the lamp in the socket of a light fixture. The electrical connection to the socket may be made with a screw-thread base, two metal pins, two metal caps or a bayonet cap. It is worthy to state here that there are several types of electric lamps; which, according to (https://en.m.wikipedia.org/wiki/Lamp_electrical component), such as: Incandescent lamp, LED lamp, Compact fluorescent lamp, Gas-discharge lamp, Arc lamps, etc. But since the crux of this study is on switching from the most commonly used environmentally unfriendly electric lamps in (theatres and homes); to a most environmentally friendly one that can better replace the environmentally unfriendly ones, the analysis in this study is focused on: incandescent lamps, fluorescent lamps, and the LED lamps.

Incandescent Light Bulbs

The term incandescent light bulb or incandescent lamp or incandescent light globe are used interchangeably in this study and they mean the same thing as an electric light which produces light with a wire filament heated to a high temperature by an electric current passing through it, until it glows. The hot filament, known as tungsten, is a metal with the highest melting point - 3695 Kelvin temperature; lowest vapor pressure, and greatest tensile strength out of all the metals. (culled from: http://scienceline.ucsb.edu/getkey.php?key=2548).

The filament is protected from oxidation with a glass or quartz bulb that is filled with inert gas. In a halogen lamp, filament evaporation is prevented by a chemical process that redeposit metal vapor onto the filament, thereby extending its life. The light bulb is supplied with electric current by feed-through terminals or wires embedded in the glass. When lit, "they create a more unnatural orange and red ambience than the fluorescent bulbs"… and the LEDs. (Culled from: http://www.ehow.com/list_6367767_environmetal-effects-incandescent-light-bulbshtml).

Negative Effects of Incandescent Light Bulbs on the Theatre and the Environment:

According to an online article on the Environmental effects of Incandescent Light Bulb, (Culled from: http://www.ehow.com/list_6367767_environmetal-effects-incandescent-light-bulbshtml), the negative effects of incandescent lamps include:

1. Energy Consumption: ninety percent of the energy that an incandescent light bulb burns is wasted as heat. According to a Wikipedia article on "Electrical Efficacy",

> …efficiency should not be confused with effectiveness: a system that waste most of its input power but produces exactly what it is meant to is effective but not efficient. The term 'efficiency' makes sense only in reference to the wanted effect. A light bulb, for example, might have 2% efficiency at emitting light yet still be 98% efficient in heating a room (In practice it is nearly 100% efficient at heating a room because the light energy will also be converted to heat eventually, apart from the small fraction that leaves through the window). An electronic amplifier (example, a loud speaker), that delivers 10 watts of power to its load while drawing 20 watts of power from a power

source is 50% efficient. (That is 10/20 x 100% = 50%)
(culled from https://en.m.wikipedia.org/wiki/electrical_effiency). Therefore, in terms of efficiency, the incandescent filament lamps are very poor.

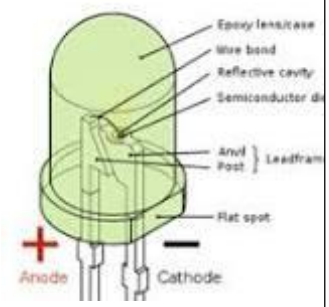
2. Excessive Heat Generation: When used for stage lighting (especially in poorly ventilated theatres), lighting instruments with incandescent lamps generate so much heat that makes performers to sweat profusely, uncomfortable, wash off make-ups from performers bodies; thus resulting in distorting and/or destroying the intended illusion. One of the many scenarios where the inconveniences caused by the heat from incandescent light occurred on May 30th, 2013 at the Department of Theatre and Media Arts, Federal University Oye-Ekiti, Ekiti, Nigeria; during a theatrical production of Ola Rotimi's *The Gods Are Not To Blame,* in which Gondo Isaac, the actor playing the lead role (King Odewale), intermittently fell out of character. When asked by this researcher, what the problem was, he retorted: "the heat was too much. Being that I appeared in almost all the scenes in the play, I was almost constantly under the heat of the light so I was sweating so profusely, at some points I could not bear it anymore – I fell-out of character." This attests to one of the adverse effects of incandescent lights; hence, the unsuitability and undesirability of incandescent lamps in theatre lighting.

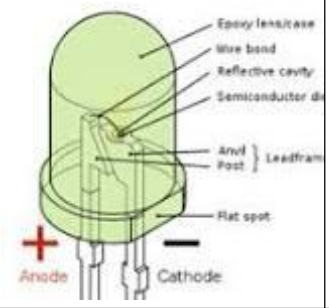
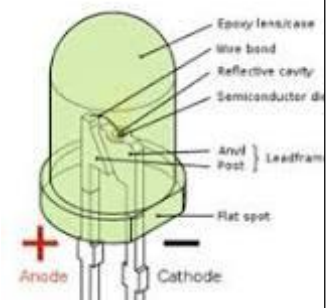
3. Mercury Content: mercury is a toxic substance. And chances are that at least 50% of generated light is by coal-powered plants; which actually features mercury as well as other types of pollution. According to an online article on: The Environmental Effects of Incandescent Light, "an incandescent bulb will contribute nearly twice as much mercury to the environment over its lifetime than a broken, exposed compact fluorescent would." (Culled from: http://www.ehow.com/list_6367767_environmetal-effects-incandescent-light-bulbshtml).

4. Bulb Disposal: the incandescent light bulbs contain lead at levels that exceed hazardous waste limit. "Lead is acutely and chronically poisonous to aquatic organisms and mammals. Even in small concentration, lead poisoning may cause neurotoxic and immunologic problems. Lead can also cause fetal damage in humans and reduce fertility." This means that if incandescent bulbs are thrown away in the regular garbage bins or landfills, "this lead will sooner or later find its way into nature". (culled from: www.renewablesathome.com/recycling/lighting=sources-hazardous-waste)

5. Spectral Sensitivity: it worthy to point out that the use of artificial light rays in theatrical productions is basically to simulate the visibility that the sun and/or moon produces (as the case may be); hence, in terms of spectral sensitivity of the human eye, the rays of light produced by incandescent lamps (which is slightly orange-like) is at variance with the crystal clear rays of a day time sunlight. Whereas, crystal clear rays from the Light Emitting Diodes are more like the day time sunlight; hence, they are more suitable.

Table 1: Comparison Chart of LED Bulb vs. Incandescent Bulb vs. Compact Fluorescent Bulb

A] ENERGY EFFICIENCY	**Light Emitting Diodes (LED) Bulb**	**Incandescent Bulb**	**Compact Fluorescent Bulb**	**Remark**
				
1) Average Life Span	50,000 hours	1,200 hours	8,000 hours	LEDs are over 40 times more durable than the Incandescent bulbs
2) Light Output **(**lumen**)** in equival	6 -8 watts	60 watts	13 -15 watts	LEDs requires very little energy to produce as

	ence to a 60 watts incandescent bulb				much or even brighter illumination than Incandescent or Fluorescent bulbs
3)	Kilo-watts of Electricity used (30 incandescent bulbs per year equivalent)	329 kwh/yr	3,285 kwh/yr	767 kwh/yr	Incandescent bulbs are energy dissipaters. They about 10 times more energy LEDs for the same output.
B] ENVIRONMENTAL IMPACT					
1)	Contains the TOXIC Mercury	No	No	Yes	Mercury is toxic to health & environment; and are found in fluorescent bulbs.
2)	Carbon Dioxide Emissions (30 bulbs per year)	451 pounds/year	4,500 pounds /year	1051 pounds/year	Lower energy consumption decreases: CO2 emission, sulfur oxide, and high-level nuclear waste
3] OTHER USEFUL FACTS		**Light Emitting Diodes- LED** 	**Incandescent Light Bulb** 	**Compact Fluorescents Bulb** 	
1)	Sensitivity to low temperatures	None	Some	Yes	Fluorescents may not work under negative 10 degrees Fahrenheit

				or over 120 degrees Fahrenheit
2) Sensitivity to humidity	No	Some	Yes	LEDs stand out
3) On/Off Cycling Switching CFL on/off quickly, in a closet for instance, may decrease the life span of the bulb	No effect	Some	Yes – can reduce lifespan drastically	LEDs are resistant any on/off cycling effect
4) Turns on instantly	Yes	Yes	No – takes time to warm up	
5) Failure Modes	Not typical	Some	Yes – may catch on fire, smoke, or omit an odor	

A perusal of the above analytical comparison reveals that in terms of usefulness, the Light Emitting Diodes (LEDs) are more advantageous than the Incandescent filament bulbs and the Fluorescent bulbs.

Advantages of LED Lamps

1. "LED lamps have a lifespan and electrical efficiency that is several times better than incandescent lamps and significantly better than most fluorescent lamps, with some chips able to emit more than 100 lumens per watt." (Culled from: (https://en.m.wikipedia.org/wiki/LED_lamp)

2. Like incandescent lamps and unlike most fluorescent lamps (e.g. tubes and compact fluorescent lamps or CFLs), LEDs come to full brightness without need for a warm-up time; the life of fluorescent lighting is also reduced by frequent switching on and off. (Culled from: (https://en.m.wikipedia.org/wiki/LED_lamp)

3. A significant difference from other light sources is that the LED light is more directional, i.e., emitted as a narrower beam. Hence, light-spillage (especially in theatre lighting) is minimal. For applications where non-directional light is required, either a diffuser can be used, or multiple individual LED emitters are used to emit in different directions.

4. LED lamps are used for both general and special-purpose lighting. Where colored light is needed, LEDs that inherently emit light of a single color require no energy-absorbing filters.

5. White-light LED lamps have longer life expectancy and higher efficiency (more light for the same electricity) than most other lighting when used at the proper temperature. As of 2010 some LED lamps replaced higher wattage bulbs; for example, one manufacturer claimed a 16-watt LED bulb was as bright as a 150 W halogen lamp.

6. LED sources are compact, which gives flexibility in designing lighting fixtures and good control over the distribution of light with small reflectors or lenses. Because of the small size of LEDs, control of the spatial distribution of illumination is extremely flexible. The light output and spatial distribution of an LED array can be controlled with no efficiency loss. LEDs using the color-mixing principle can emit a wide range of colors by changing the proportions of light generated in each primary color. This allows full color mixing in lamps with LEDs of different colors.

CONCLUSION

From this study, it is very glaring that the continuous use of incandescent filament lamps in theatre lighting equipments (and in homes), is a continuous threat to the ecosystem. This study makes it clear that energy efficiency is an imperative part of the initiative towards a greener and more stable environment; hence, the need for the transition from the use of incandescent bulbs to LEDs; since light emitting diode bulbs decreases energy use and electrical cost. More so, unlike other bulbs like the Compact fluorescent lamps, LED bulbs do not contain mercury, so, recycling them is easier and safer.

Light/lighting in the theatre are required for illumination and other effects; but not for generating heat; hence, the unsuitability and undesirability of incandescent lamps (especially now that there is a better option – the LEDs). Also, the use of artificial

light rays in theatrical productions is basically to simulate the visibility that the sun and/or moon produces (as the case may be); hence, in terms of spectral sensitivity of the human eye, the rays of light produced by incandescent lamps (which is slightly orange-like) is at variance with the crystal clear rays of a day time sunlight. Whereas, crystal clear rays from the Light Emitting Diodes are more like the day time sunlight; hence, they are more suitable.

A perusal of the above analytical comparison reveals beyond any reasonable doubt, that in terms of usefulness: environmental friendliness, lifespan, efficiency, long-term cost effectiveness, and so on; the Light Emitting Diodes (LEDs) are more advantageous than the Incandescent filament bulbs and the Fluorescent bulbs. Therefore, if Nigeria and every other nations are really committed to the fight against environmental degradation, they should discourage the further use and importation of incandescent filament lights into their domain by further sensitization of their citizens on the dangers of incandescent filaments bulbs, Lead and Mercury containing lamps, also educate them on how best to dispose those already in circulation (especially when broken and/or when they have burnt out). Due to the advent of a much more innovative and environmental-friendly and theatre lighting suitable lamp – the LED, it will not be out of place to state that: the incandescent filament lamps have outlived their usefulness, thus, it is high time they be out-rightly proscribed and replaced by the light emitting diode lamps – the LEDs.

RECOMMENDATION

This study recommends that in furtherance of the measures by national and international bodies to ensure adherence to environmental disaster risk management measures that will bring about sustainable global development, bodies like the World Health Organization, and indeed the United Nations should make stringent policies that would compel/encourage electric lamps manufacturing companies to transit from manufacturing incandescent lamps for theatre lighting equipment to Light-Emitting-Diodes. This will indeed bring about an era of a new trend of theatre lighting lamps that are artist and eco-friendly.

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