Impact of Light Pollution on Environment and Strategies to Reduce the Adverse Effects

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Abstract*— The invention of the electric light bulb 150 years ago was one of the most transformative milestones in history. But the new form of light, the artificial light expanded numerously to a state wherein it started becoming an adulteration to the environment. Light pollution, also known as photo pollution or luminous pollution is the inappropriate or excessive use of artificial lighting. Light pollution is important and should be addressed as it poses a serious threat to the environment. It misuses finances and resources while it puts the environment in danger and destroys the vision of night sky. Light pollution is usually caused by the billboards, streetlamps, homes and office buildings. Poorly designed residential, commercial, and industrial outdoor lights also contribute significantly to light pollution. Artificial light impacts bird migration patterns, hinder frogs from mating, averts the spawning of corals, etc. Too much light can also disorient sea turtles when they come on land to lay their eggs. Excess light can affect the mankind by destroying the photoreceptor cells in the retina damaging the eyesight, and is also a prime suspect of cancer. Every year a lot of money is spent for burning oil and coal for the production of electricity which is in turn is being wasted by unnecessary lighting. Luminous pollution, unlike other forms of contamination and waste, can be contained and reduced by improving outdoor lighting practices. Efforts are being made to counter the rise in excess light including development of alternate energy efficient light bulbs and smarter directional lighting designs. Outdoor lighting serves a purpose to provide visibility and safety at night, but lighting that exceeding its limit should be properly troubleshooted.

Indexed Terms*— light pollution. Artificial light, illumination

I. INTRODUCTION

Light pollution, or artificial light at night, is the excessive or poor use of artificial outdoor light, and it disrupts the natural patterns of wildlife, contributes to the increase in carbon dioxide (CO2) in the atmosphere, disrupts human sleep, and obscures the stars in the night sky. Discovery of artificial light was one of the most prodigious inventions in history. Like many other products, the LED light was discovered by accident. Artificial light was invented so that we can lighten up dark places and our home at night. Today, other significant uses have been added to light's primary purpose of illuminating objects and things. Lights are being used in billboards and establishment signs as a promotional tool filled with lighted bulbs so that they can attract attention of passers-by. Lights are especially important in warning signs on the road seen at night, which help in saving lives. Lights and electricity permit us to do tasks any time of the day making us more productive and efficient. But we the ones who brought this humongous invention, started using this resource immoderately, creating a matter on contention. A little more than 100 years ago, you could walk outside at night even in a city and see the Milky Way galaxy arch across the night sky. The expanded use of light at night is due to the fact that humans, who are diurnal (non nocturnal) in nature are trying to extend their activities into the dark hours. Most of us are familiar with air, water and land pollution, but did you know that light could also be a pollutant? The excessive or inappropriate usage of artificial light results in light pollution. Light pollution like other forms of pollution is a form of waste energy that can cause adverse effects and degrade environmental quality. According to the statistics, the usage of artificial lighting increases by 20% each year, depending on the region, and, there is an urgent need for light pollution policies that surpass energy efficiency to include humans, animals and the environment. Figure 1 shows the proportion of light being used and wasted which is 60% and 40% respectively. Figure 2 shows the impact of light pollution on various aspects.

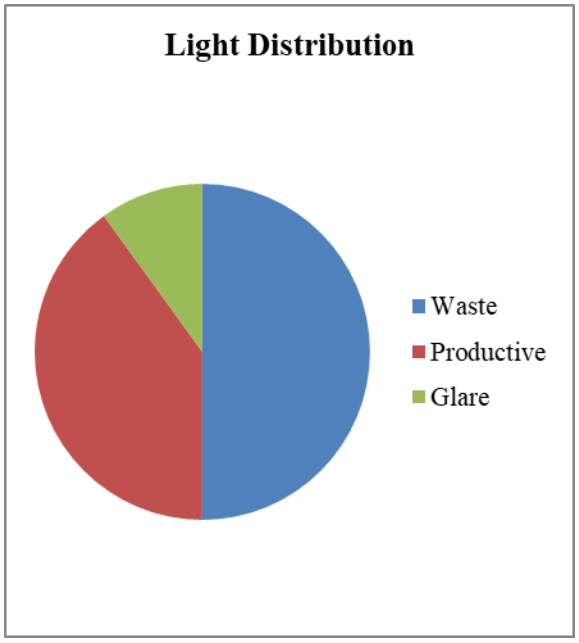

Fig.1: Usage of Light Distribution

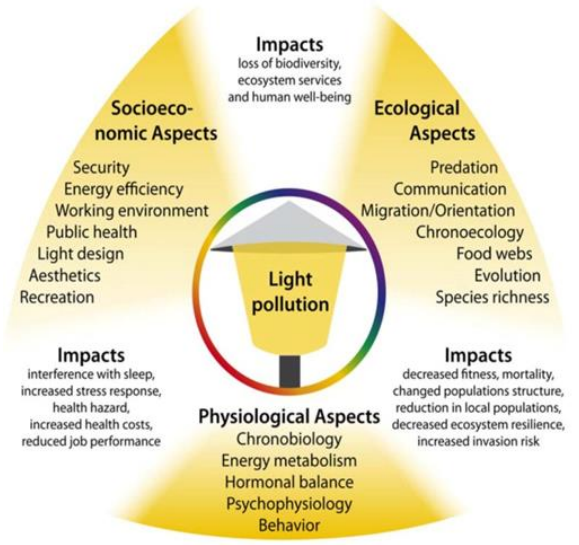

Fig. 2: Impact of Light Pollution

II. LITERATURE SURVEY

2.1 The history of night time illumination

The public night time lighting was originated in the seventeenth and eighteenth centuries, noting two important points. The first is that despite technical improvements in oil lamps, lighting was still poor and cities were mostly dark. Second, old habits did not die easily and darkness still represented a time both sacred and dangerous for many. In certain places it remained custom to stay home, except for special occasions, and devote evenings to prayer and rest.

The first monumental technical development in nighttime lighting came at the turn of the nineteenth century with gaslight. Gaslight was first demonstrated publicly in 1807, in London, and over the next few decades it was quickly adopted across Europe and North America. Gaslight was followed by the invention of electric lighting in the latter half of the nineteenth century which was the most profound technological development in lighting, and arguably one of the most important developments of modern infrastructure. Any scarcity of urban nighttime illumination was quickly diminishing as electrification spread across North America and Europe during the twentieth century, developing alongside urbanization and the growth of transportation networks.

A lengthening of the day has effectively been achieved, creating unmistakably modern nights where the various facets of night life can occur, and where many daytime activities can continue well into the night. But this has come with unintended consequences.

2.2 The emergence of light pollution

Light pollution started to become a problem in the early 20th century, around the time cities began adopting electric lighting. The consequences of artificial nighttime lighting have been under debate since the nineteenth century, and some criticisms of artificial nighttime lighting can be found even earlier. The concept of light pollution coalesced in the early 1970s, amid a climate of political activism, rising environmental awareness, and an energy crisis. Then during the 1973 energy crisis urban areas saw an increase in energy conservation efforts, resulting in decreases of public lighting. Astronomers used the anti-waste strategies of the time to fight excess artificial nighttime brightness, which is when, according to Sperling, ‘the struggle took on its current aspect’. In the year 1994, an earthquake caused a power outage in Los Angeles and the residents who have never seen the milky way called the local emergency and observatories to report a “strange giant silvery cloud “ in the sky.

In 2010, the UN stated that "For the first time in history, more people live now in urban than in rural areas," and that "2/3 of the Earth's population have never seen a truly natural night sky. Most of those live under a perpetual orange dome.

III. MEASURING LIGHT POLLUTION

Measuring light pollution is an intricate process because the natural atmosphere is not completely dark due to airglow and scattered light. To obtain an accurate measurement, scientists use satellite images of Earth at night to determine the number and intensity of the light sources, and calculate the total sky brightness. Amateur and professional astronomers can also use a Sky Quality Meter, a handheld device that measures sky brightness, to document and compare different areas. Mobile apps like Dark Sky Meter and Loss of Night allow anyone to measure sky brightness. Another way to gauge light pollution is the Bortle Scale, a nine-level rating system that measures sky quality by providing observable standards. The scale ranges from one, an excellent dark-sky site, to nine, an inner-city sky, and specifies observable criteria for each class. Due to light pollution, the night sky over many of our cities is hundreds of times brighter than a natural, starlit sky. This skyglow hides the stars from our sight and prevents us and all life on Earth from experiencing a natural night, even in areas hundreds of miles away from urban development. A lux (lx) is a unit of illumination equal to 1 lumen per square meter and the candela (cd) is the basic SI unit of luminous intensity. Hyderabad has highest "light pollution in India" with artificial brightness of 7,790µcd/m^2 (unit of luminous intensity per square metre) followed by Kolkata at 7,480µcd/m^2 and New Delhi at 7,270 µcd/m^2. Bhubneshwar recorded lowest at 2,910 µcd/m^2. Table 1 shows the impact of various light sources on sky glow. Table1 shows the impact of various light sources on sky glow.

Table 1: Impact of various light sources on sky glow.

Type Of Light Source	Colour	Luminous Efficacy(In Lumens Per watt)	Sky Glow Impact (relative to LPS)
LED street light(white)	Warm white to cool white	120	4-8
Low pressure Sodium(LPS/SOX)	Yellow or amber	110	1.0
High pressure sodium(HPS/SON)	Pink or amber white	90	2.4
Metal halide	Warm white to cool white	70	4-8
Incandescent bulb	Yellow or white	8-25	1.1

$$\text{Relative light pollution} = \frac{\text{man made part of any photometric or radiometric quantity}}{\text{Natural part of the same quantity}}$$

IV. TYPES OF LIGHT POLLUTION

Photo pollution occurs in a variety of forms, including light trespass, glare, sky glow, and light clutter. One source of light can result in multiple forms of pollution. Identification of each form of light pollution is described in this section.

- Light trespass - Trespass, also known as spill light, occurs when a light fixture casts illumination beyond the property lines, unintentionally illuminating other homes, businesses, or areas. Spill light is the most subjective form light pollution because there are no guidelines to determine when, where, or how much light is unwanted. A common example of spill light is light from a streetlight coming through a window and illuminating a bedroom, light from outdoor wall lights that direct light up towards the sky rather than towards the ground, or light from a neighbor's floodlight or security light shining over the fence and illuminating others property.

- Glare - Glare is the visual sensation one experiences when stray light, light in the visual field, is greater than the light to which the eyes are adapted. Glare, depending on the intensity, can result in reduced contrast, color perception, and visual performance. Glare occurs in the following three forms:

- Discomfort Glare – Discomfort glare is also known as psychological glare, and is the most common type of glare. Psychological glare occurs when lighting causes annoyance or irritation, but does not decrease visual performance and physical discomfort is short term. Discomfort glare can be reduced by installing a light dimmer to dim lights, such as recessed lights, in houses.

- Disability Glare – Disability glare, also known as veiling glare, occurs when stray light scatters in the eye, producing a veil over the retina, affecting visual performance. Veiling glare reduces contrast as well as color and spatial perception, which can lead to unsafe driving conditions. Older drivers are more prone to experience disability glare while driving.

- Blinding Glare – Blinding glare, also known as absolute glare or dazzle, occurs when a light source impairs the field of vision, preventing the eye from seeing anything but the light source. Visual performance may remain affected for some time well after the incident.

- Sky Glow - Sky glow originates from natural and man-made sources; however, poorly designed and targeted artificial lights are the main causes of sky glow. Sky glow occurs when light is emitted directly into the atmosphere, accidently or purposefully, where it is scattered by dust and gas molecules, creating a dome-like orange glow that covers the night sky. The glow reduces the contrast between the stars and the galaxies in the sky, making celestial objects difficult to see even with a telescope. Light domes also affect the polarization of moonlight, which nocturnal animals use to navigate. Glow domes are visible in cities and towns throughout the world, and they appear in a variety of sizes such as large domes over metropolitan hubs or small domes above over-illuminated commercial areas and sport complexes or stadiums. Cloud coverage, snow, trees, and the quantity of dust and gas molecules in the atmosphere can amplify sky glow.

- Light Clutter - Light clutter is the excessive grouping of bright lights that cause confusion and distract from oncoming or surrounding objects. Light clutter is visible on roads surrounded by unshielded street lights and brightly lit advertisements or signs. This creates a hazardous environment for drivers and pilots because it competes with traffic and navigation signals. Clutter contributes to other forms of light pollution, including light trespass, glare, and sky glow. Figure 3 shows light distribution and its actual usage.

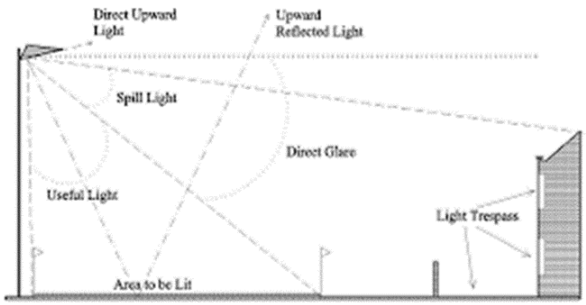

Fig. 3 Light Distribution showing actual usage

V. CAUSES OF LIGHT POLLUTION

Luminous pollution is caused by using outdoor lights whenever and where ever they are not necessary. Poorly designed residential, commercial, and industrial outdoor lights also contribute significantly to light pollution. Unshielded light fixtures emit more than 50% of their light skyward or sideways. In many instances, only 40% of the light emitted actually illuminates the ground. It is caused as a result of industrialization and modernization. Light pollution is usually caused by the billboards, streetlamps, homes and office buildings. Poorly designed residential, commercial, and industrial outdoor lights also contribute significantly to light pollution. The various causes of light pollution are discussed in the next paragraph.

- Night Sports Stadiums: The floodlights used in sports stadiums and grounds specialized for major sports events frequently contribute to light pollution since the lights used are very powerful and end up disrupting the natural illumination at night. Also, the glares from the lights are reflected upwards, therefore, brightening the skies at night. These are particularly the big lights focused on the stadium and the surrounding areas.

- Car Lights and Street Light: Roadway lighting are the biggest contributions to light pollution , especially in major cities and on the highways. This encompasses the hundreds of kilometers of powerful streetlights that remain lit the whole night on a daily basis. When this is combined with the car lights during the night, the total roadway lighting contributes a great deal of light which brightens the skies and directs light to unintended areas. According to a survey on light pollution effects centered on roadway lightings, light emitted from roadways is approximated to constitute about 35% to 50% of all light pollution.

- Residential Places: Too much light intruding into the houses at night from outdoor lights makes up light pollution in the residential areas especially owing to the spillover and glare type of lights. Overhead, landscape, and to add aesthetics to the view frequently causes a nuisance at night since they cause disturbance to people driving or walking in the areas. Besides, they contribute to the brightening of the skies and interference with natural illumination.

- Commercial Advertisements and Electronic Billboards: Within major cities and highways, it's a common to find large electronic displays and bill boards lighting immediately darkness sets in. Very powerful lights light many of these electronic displays. As such, the lights often wind up dispersed or reflected to unintended areas such as the skies and the adjacent areas brightening the environment and disrupting the natural illumination during the night. Pubs, gaming and shopping centres, discos, and restaurants are also some of the leading areas within cities that disperse a lot of display lights to attract customers which cause light pollution since the lights used are dispersed haphazardly.

- Airports, Bus Stands and Train Stations, and Public Centers: Public centers such as city parks, bus and train stations, and airports are commonly lit by powerful lights which are not shielded from the spill over and glare effects thus producing a lot of light to the skies and unintended surrounding places. Furthermore, because most of these places still use the traditional lighting systems, they contribute to extensive light trespass, glare, and clutter at night.

- Carefree Culture: Many times, people leave lights on at their offices or at home thereby creating some form of light pollution. This particularly fits the scenario regarding residential light pollution. Simply, leaving the lights as they are on all night is an irresponsible and carefree culture that not only leads to wastage but also light pollution.

- Urbanization and Dense Population: Urbanization and dense population growth rate are the underlying factors contributing to too many residential areas, businesses, and highway expansions which finally lead to light pollution.

VI. CONSEQUENCES OF LIGHT POLLUTION

Luminous pollution has dire effects on our environment and resources of energy as well as wildlife ecology and astronomical research. Light pollution also affects the quality of life and safety of humans. Here are some of known side effects of light pollution.

- Environment: Excessive night time lighting releases more than 12 million tons of carbon dioxide, the most serious greenhouse gas, into the atmosphere each year. It would take nearly 702 million trees to absorb the carbon dioxide produced by wasted light. Photo pollution increases air pollution by suppressing a naturally occurring radical that cleans the air at night. However, artificial lights from buildings, cars, and streetlights, although 10,000 times dimmer than sunlight, affect nitrate radical and slow down the

cleansing process by 7%. Artificial light also increase the chemicals for ozone pollution by 5%.

- Energy: Wasted light results in energy waste. 30% of all light emitted by public outdoor light fixtures is wasted, which amounts to 22 Terawatt Hours (TWh)/year of wasted electrical energy. The total amount of wasted electrical energy each year is enough to illuminate over 11 million homes and power over 777,000 cars.

- Wild life: Luminous pollution affects the feeding, sleeping, mating, and migration cycles of all wildlife. Wildlife can also experience disorientation of time when there is too much artificial light at night.

- Mammals: Mammals such as bats, raccoons, coyotes, deer, and moose can experience difficulty foraging for food at night due to over illumination. They risk exposure to natural predators and increased mortality due to night vision impairment. They also experience a decline in reproduction that leads to a shrinking population.

- Birds: Birds such as owls and nighthawks use moonlight and starlight to hunt and migrate at night. Hence due to artificial lighting they experience difficulty in carrying out these tasks. Artificial lights sources can overwhelm natural light sources, causing birds to be drawn to or fixated on the artificial lights. This results in birds deviating from their intended migration route, flying until they experience exhaustion and collapse, and becoming prey to other animals. Marine birds such as albatrosses are known to collide with lighthouses, wind turbines, and drilling platforms at sea due to their bright lights.

- Amphibians: Sky glow affects amphibians such as frogs, toads, and salamanders in marshes and wetlands. The orange haze confuses and disorients them, which causes a decrease in feeding and mating. It also impairs natural instincts that protect amphibians against natural predators and the elements.

- Reptiles: Reptiles such as sea turtles are greatly affected by light pollution. Female turtles nest on dark, remote beaches, but bright coastal lights prevent them from finding safe nesting areas for their eggs preventing them from depositing their eggs in an unsafe area or the ocean. Sea turtle hatchlings instinctively crawl toward the brightest part on the beach excessive lighting on the beach or near the shore confuses the hatchlings and causes them wander away from the ocean. The hatchlings may be eaten by predators, run over by vehicles, drown in swimming pools, or die from dehydration or exhaustion.

- Insects: Insects such as moths are naturally attracted to light and may use all their energy to stay near a source of light. This interferes with mating and migration as well as makes them vulnerable to natural predators, which reduces their population. This also affects all species that rely on insects for food or pollination.

- Astronomy: Light pollution alters our view of the sky and stars, but no group of people is more affected by this phenomenon than astronomers. Light spill and sky glow interferes with astronomical equipment, and makes viewing faint celestial bodies difficult even with the aid of a telescope. In order to conduct observation and research, astronomers require dark skies.

- Humans: Humans, like plants and wildlife, are regulated by circadian rhythms, the physical, mental and interactive changes that occur in a 24-hour cycle. Disrupting these rhythms can result in a variety of health problems, including sleep disorders, anxiety, depression, diabetes, cancer (particularly breast and prostate cancer), cardiovascular disease, immunological disorders, and obesity. Melatonin is affected by light pollution which results in anxiety and mood disorders, insomnia, and elevated estrogen or progesterone ratio. Figure 4 shows the cause-and-effect diagram for light pollution.

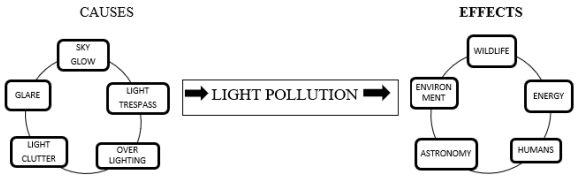

Fig 4: Cause and effects of light pollution

VII. STRATEGIES FOR PREVENTION OF LIGHT POLLUTION

Luminous pollution, unlike other forms of contamination and waste, can be contained and/or reduced by improving outdoor lighting practices. Section 7 describes some simple strategies to reduce light pollution without sacrificing comfort or safety.

- Use of Warm white lighting source: Use compact fluorescent lamps (CFL) and LED bulbs that produce warm white lighting. Many LED lights emit a blue short wavelength light that scatters easily into the atmosphere, which causes eyestrain, impairs night vision and adds to light pollution.

- Shielded lights: Choose outdoor light fixtures that are shielded, which means there is a solid cap above the light bulb that prevents light from being emitted directly to the sky, to minimize sky pollution. You can shield exiting fixtures by buying and installing reasonably priced shades.

- Light fixtures with cutoff angles: Select exterior light fixtures with cutoff angles to prevent light from escaping above the horizontal plane, minimize up lighting, and reduce high-angle brightness. Cutoff lighting emits illumination down to the ground where it's most needed and in many cases, improves visibility. Fig 5 shows appropriate Positioning of Light. Figure 6 shows the effects of shielding on light pollution. On the far left, an unshielded light spreads light all over. On the far right, a fully shielded light directs the glow to where it is needed, no further. one can see the effects on the sky above the lights. Figure 7 shows a comparison between Modern to Erstwhile Lighting system. Also figure 8 shows appropriate use of fixtures for reducing light pollution

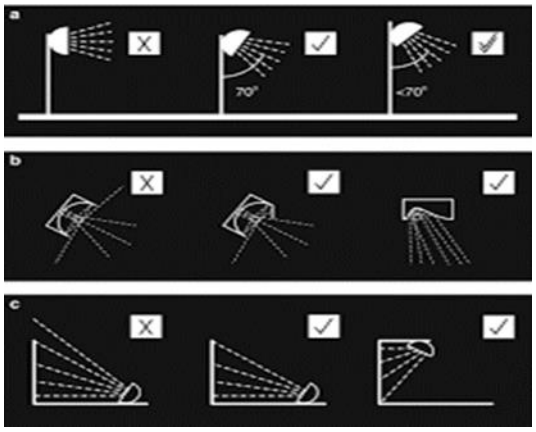

Fig 5: Appropriate Positioning of Light

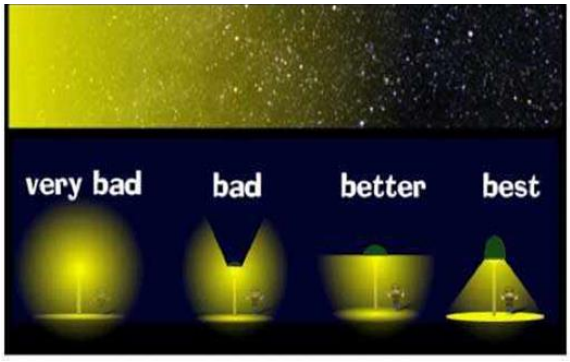

Fig 6: Focused approach of lamination

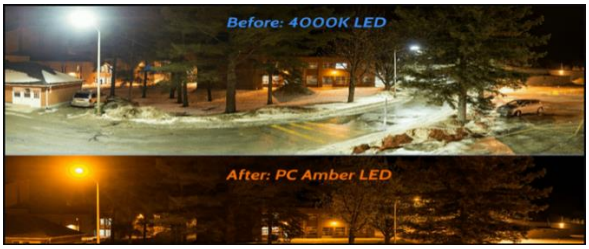

Fig7: Comparison between Modern to Erstwhile Lighting system

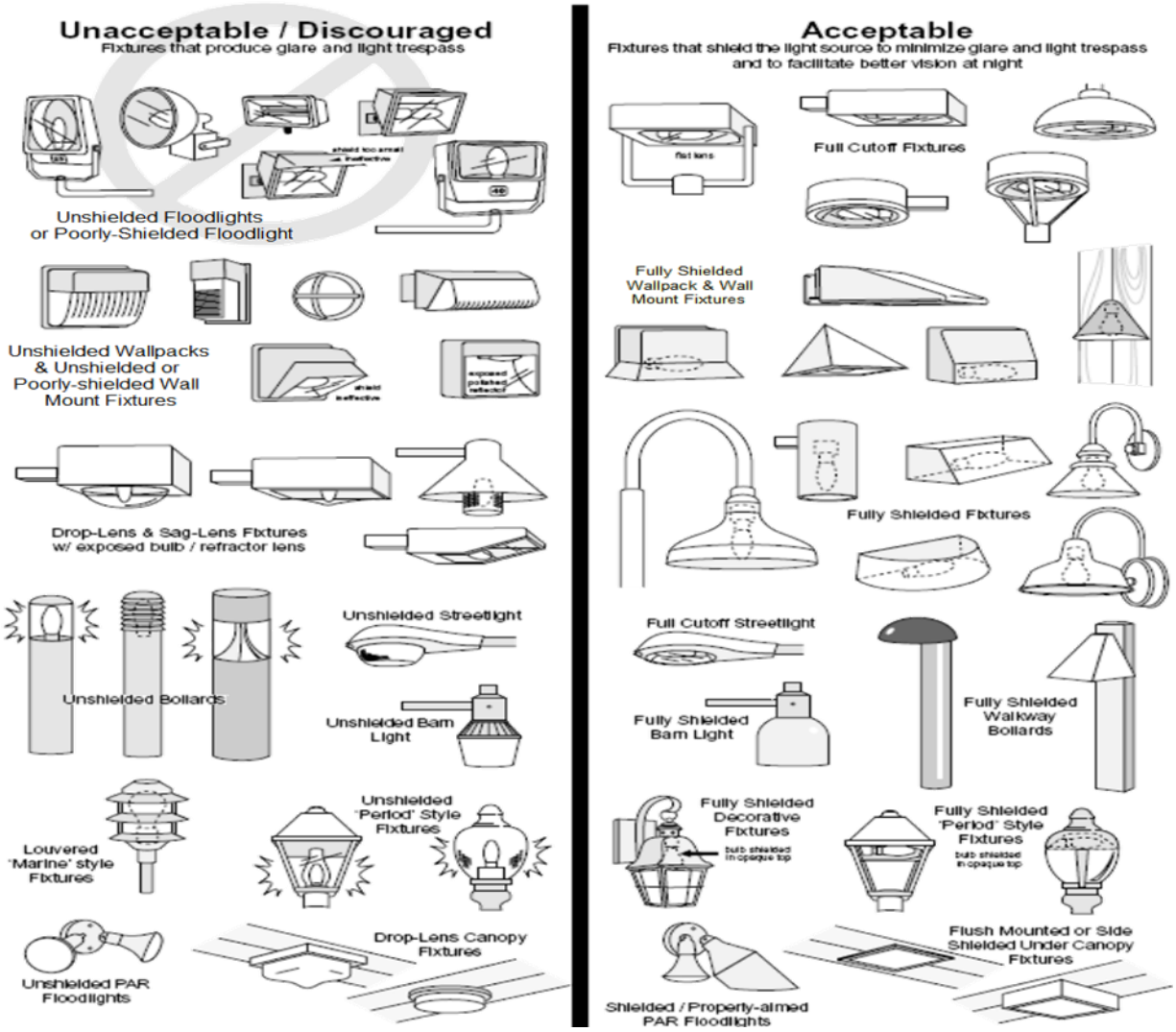

Fig 8: Appropriate fixtures to be used for lighting

- Using Lights with Sensor: By Installing motion sensors on outdoor fixtures so that they can turn on when needed and turned off after a short time. It should be made sure to test and adjust the motion detector's sensitivity as needed to prevent the lights from turning on and off unnecessarily.

- Using Certified lights: By Using IDA certified Dark Sky Lighting, which is designed to minimize glare, light spill, and sky glow. Dark-sky approved light fixtures are available in a variety of chandeliers, flush mounts, pendants, and wall sconces. People living near the beach should use certified Turtle Safe Lighting. These shielded light fixtures produce a long wavelength light, which does not scatter easily, and should be mounted low to avoid high-angle brightness.

- Turning Lights Off: Turning off any unnecessary outdoor lights when you are home for the night or before going to bed to prevent wasteful dusk to dawn lighting. If you're in doubt, turn them off by 11 PM. While you're at it, make sure to turn off indoor light fixtures, like wall lights, when you're not home or before bed to reduce energy consumption.

- Make continuous efforts: Take steps to prevent and reduce light pollution in your home, work, and community. Close the blinds and curtains to prevent light spill. Ask management to turn off or

dim office lights after all workers have left the property for the day to prevent light and energy waste. Petition local business owners to dim after-hour signs to prevent glare and light clutter. Propose lighting ordinances to your local and state governments to reduce light pollution.

VIII. CONCLUSION

- It can be concluded that, light pollution is reversible. It can be abated directly by changing human habits. Shielded lights for outdoor fixtures should be fixed in direct light down position, instead of up. Indoor lighting should be structured to focus inside premises at night with closed drapes and blinds.
- Lower wattage bulbs will also help in reducing light pollution. The bulbs or lights while getting manufactured in industries should be programmed in such a way that the source of light (bulb) should analyze the number of hours it should be in full wattage. During the dawn it should be able to reduce its wattage and get poorly lit on its own.
- To reduce light pollution, Companies can choose to forgo glaring neon signs in favor of more subtle choices.
- Local governments should reconsider which streets need extra lighting at night and which streets need less, and then act accordingly. Also government should bring a regulation Setting Limits to Light Pollution.
- Ensuring Collaboration between individuals, businesses, and government would help overcome the problems that come with living in a world that is too bright. Promotion for using dark sky, friendly lighting at homes and businesses will go a long way in saving our planet from global warming hazards.
- By bringing awareness amongst people to light devices only when it is required, would go a long way in reducing the light pollution and save power consumption.

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