GLARE POLLUTION IN URBAN AREAS

Eshetu Temesgen Gelan*
Executive Director- ETG Designers and Consultants Plc.

ABSTRACT

Glare pollution is an unnatural element in the global environment that has emerged as a result of human beings inefficient and destructive use of technology and resources. It refers to the tangible and the intangible interaction of natural light reflecting off synthetic materials, for example sunlight on rooftops, walls, windows, curtain walls, billboards, and different reflective surfaces. It also refers to artificial light in general, such as light trespass, light spills, high power beam headlights, florescent and incandescent. Discomfort, annoyance and a decline in visual performance are some effects caused by glare pollution. This is the result of utilization of non-renewable energy forms, poor design, and inefficient use of renewable resources which have to be managed by architects, planners, engineers and Associates.

This study, gives due attention towards the design and construction sector and identified how glare pollution affects buildings, how buildings lead to glare pollution, or other forms of glare pollution. The effects of both natural lighting sources and the effects of artificial lighting are examined. It also states the status of glare pollution and the solution how to reduce or eliminate the impacts. It concluded that making it illegal to consume energy inefficiently and to use non-sustainable synthetic materials in architectural design and planning, will help to mitigate all types of glare pollution.

Keywords: *glare pollution, light pollution, sky glow, artificial light, eco-friendly, green technology.*

INTRODUCTION

Glare pollution is both the cause and effect of a host of human issues and as society becomes more industrialized such pollution has become increasingly problematic. Its adverse effects on the environment and physical and psychological well-being of humanity are undeniable. Day and night, pedestrians, motorists, and even people who are indoors are subjected to the visual discomfort it causes. But it is more than an annoyance. The high light contrast that it creates is a serious safety hazard for those on or near the road as it can be momentarily blinding. In addition, glare pollution is the result of electricity and energy being wasted by the use of artificial lighting that is harsh rather than effective. The ecosystem can no longer afford this type of pollution.

Since glare pollution can come into being at many stages of the design and construction process, many people can play a pivotal role in reducing it as well. Likewise, since it is influenced by so many, solving will require extensive cooperation.

Glare pollution is a relatively new research topic in the field of environmental architecture and engineering. This study shed new light on the topic and help open path for further analysis, exposing the connections between legal, ecological, psychological, technological, and industrial aspects of glare pollution (Fig.1) and the environment in its entirety. As a result of identifying the effects of glare pollution and finding and implementing the solutions, we can transform the core of environmental architecture and engineering and further the well-being of our species.

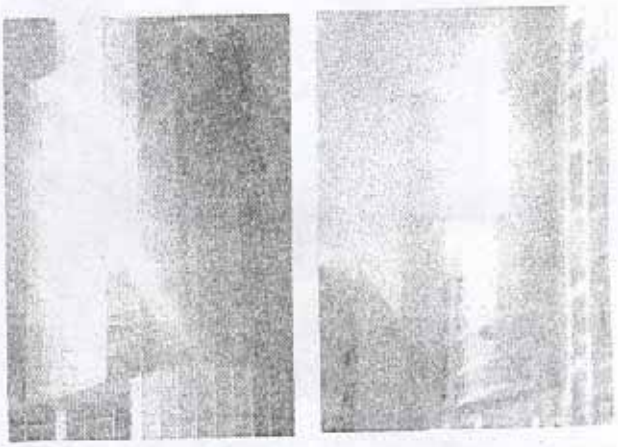

Figure 1: Glare affects the surrounding

DEFINITION AND TYPES OF GLARE POLLUTION

It is vital to define glare pollution and underline its types, which are seriously affecting humanbeings in all aspects. Glare pollution is not only created by the reflection from buildings but also other manmade and natural factors aggravate the problem.

*E-mail: etgdesigners@ethionet.et

What is Glare Pollution?

Glare is defined as "The presence, within the human visual field, of very brightly illuminated areas that degrade visual performance." [1] and as "a condition of vision in which there is a discomfort or a reduction in the ability to see significant objects or both, due to an unsuitable distribution or range of luminance, or to extreme contrasts in spaces or time." [2]

There are many factors that produce glare: The sunlight glare (direct glare), the bright sky (sky glare), or the one reflected by surfaces located in the nearby of buildings, which can be other buildings (reflected glare) (see Fig. 2). Thus glare is caused by a luminosity source that impairs or obstructs vision. It appears as a result of an improper lighting distribution within different spaces. Glare is also defined as a sensation created by light and luminance within a visual field larger than the luminance reflection to which the eyes are adapted. This luminance causes annoyance, discomfort, a decrease in visual performance, or "blinding light." [3]

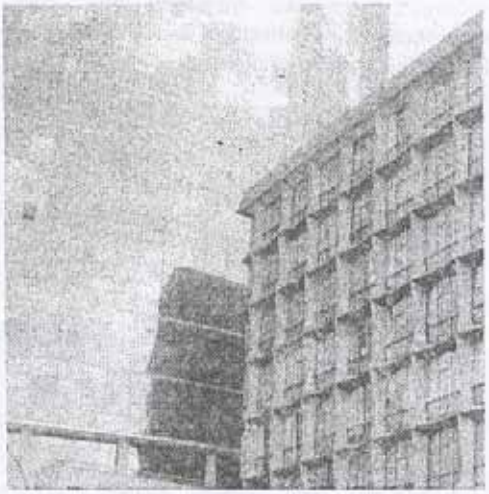

Figure.2 Glare is created by nearby building

Types of Glare Pollution

There are multiple types of glare impacting the eyes in different ways depending on intensity. While some scholars identify two types of glare: disabling veiling glare and spot glare, [4] others discuss three types: absolute blinding glare, disability glare and discomfort glare. [5]

Absolute or blinding glare occurs when the intensity of light source exceeds the maximum capacity of processing the visual information. This obstructs vision even after the lighting source has been removed and there still cannot be perceived any visual information. If the luminosity difference from one location to another is brusque and highly intense, this may cause serious damage. [6]

Blinding glare can occur in traffic, when a car that comes from an opposing way is using high beam headlights in the dark (Fig. 3). It can also occur when there is a wet, shiny road, when the low sun reflects on the asphalt's surface when driving. [7] Glare from night sky affects pedestrians and motorists (Fig. 4)

Figure 3 Automobile light affects pedestrians and motorists

Figure 4 Glare from night sky affects pedestrians and motorists

Disability glare or 'psychological glare' refers to a strong source of light that is visible on a specific point of view, located in another direction from where the subject stays. [8] The observation that the disability glare presents traffic risks diminishing the quality of driving, for instance, because of a highly illuminated construction sites. This source also mentions that this type of glare impacts observers differently depending on their ages. [9]

This type of glare produces a 'veiling luminance' that covers the view reducing the visibility performance. [10] Narisada and Schreuder also refer to this aspect: "The light from the glare source is scattered within the ocular media when it strikes the eye. It causes a light veil that seems to stretch over the complete field of view." [11]

The effects of light scatter become troublesome when there are big contrasts between different parts of visual fields at the same time. The veiling luminance as a phenomenon produced when the light from an intense bright source is scattered by the ocular media. The effect of this phenomenon is that it reduces the contrast of the image. [12]

Veiling glare is the sum of all lighting sources from the observer's view spectrum: streetlights; specular; reflections and construction lighting accumulate and create a bright background that prevents people to identify objects around them. [13] A solution for disability glare is to increase the contrast as much as it is decreased by glare but this theoretical perspective may also be applicable in an indoor environment. [14]

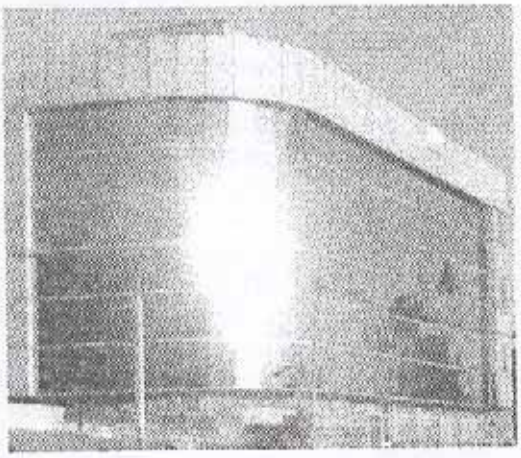

Figure 5 Glare affecting pedestrians and drivers

There are both similarities and differences between discomfort and disability glares. In an outdoor context, discomfort glare is predominant in well-lit streets, whereas disability glare merely exists. On the contrary, in poorly illuminated streets, disability light is significant, and discomfort light is almost or totally absent. [15] Moreover, unlike the disability glare, the effects of the discomfort glare decrease in time, even if the glare source has not been removed. "One may get accustomed to discomfort glare, but never to disability glare." [16] "With psychological or discomfort glare a sensation of disturbance is caused without real reduction in eye's capability. The contrast relation between object luminance and surrounding luminance depends on the absolute height of the surrounding luminance and thus on eye adaptation." [17]

Architectural Glare

Tall buildings can create shadow over considerable areas of a city, or in the neighborhood where they are located. These shadowed areas can be protected from the powerful sun in the summer season and are also less exposed to sun and warmth. "Naturally, if the building is close to the high rise, it will be shadowed for most of the year and if it is distant, it will be shadowed perhaps for only a period in a day." [18]

Veiling glare (or the disability glare) occurs when a bright spot shines on a dark background, causing diffusions. Adaptation glare is important for architectural design. This is produced when the eye adapts to the visual field, which is characterized by a mean luminance and a high variation of the luminance. This glare form might be the discomfort glare, already presented.

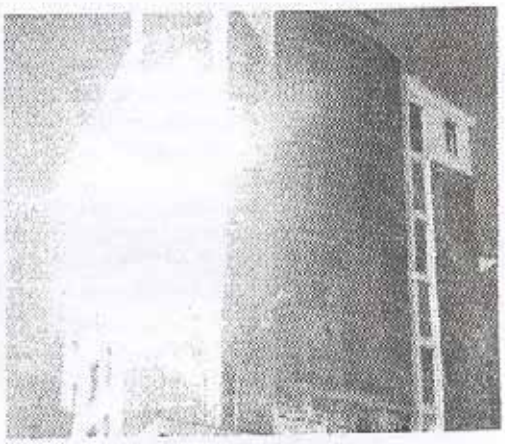

Figure 6 Glare created by sun light affects pedestrians, motorists, faunas and floras

The architectural design refers more to just positioning the building right so that it can benefit from natural light and reduce glare. It implies considering both the exterior and the interior design, and the effects of light upon both contexts. The architects' role is to design buildings that receive the outdoor natural light, but that do not show the indoor.

Impacts of Glare Pollution of Buildings

Reflections on buildings can impact neighboring buildings and can create glare reflection reciprocity between two or more buildings. The effect of the reciprocity glare could be damaging for the buildings and for the people in the buildings. The light coming from a building can affect other buildings. Glare is also a heat source. Heat impregnates the windows, glass, walls, or roofs. It is absorbed by these materials and emits long'wave radiation that remains in the building, creating a greenhouse effect and increased temperatures. [19]

This leads to the safety purpose that a building must assure. In such working or living conditions, the greenhouse effect plus the annoyance and disturbance caused by the high luminosity from outside are serious concerns.

There are serious side effects to this glare. "Reflectance of light and heat from metal and glass finished building can often cause chronic problems to motorists, pedestrians and adjacent buildings." [20] The reflection and the refractance occur because the light waves do not match the objects' natural frequencies of vibrations. An explanation for this fact stays in the atomic consistency of the objects. The electrons in the atoms that compose the objects start to vibrate when they enter in contact with a light source. However, the electrons vibrate for brief periods, with small amplitudes, reemitting the light as a light wave.

Depending on the materials' properties, the reemission of light could be generated either back, on the same side of the surface that it was stroked by light or through the material, in which case the light penetrates the object. Regarding these types of materials, whatever color(s) is/are not transmitted by such objects, are typically absorbed by them.

The appearance of a transparent object is dependent upon what color(s) of light is/are incident upon the object and what color(s) of light is/are transmitted through the object. The transparent materials absorb the color transmitted by lights, according to their own properties. The colors that are not absorbed are transmitted further through the object. Gordon states that the light that penetrates a transparent surface changes the appearance of the specific object, according to the light intensity and its predominant color. [21]

The absorbed light also depends on the surface of the materials. Moreover, it depends on the color of the materials. For instance, a darker surface absorbs the light better than a brighter surface. In exchange, the brighter surface reflects the light better than the darker surface. The absorption of light also depends on the lights striking angle into the surface. If it falls from above 90 degree, the material absorbs the light more than it reflects it. On the contrary, if the light comes from a lower angle, it will be better reflected, and less absorbed.

In addition, the working or living environment contributes greatly to the degree in which the visibility is affected by glare. For instance, contractors, working on the scaffolding are directly exposed to reflective materials (glass cladded to the building) (Fig.5, 6, 7). Moreover, the sun and sky reflect in the construction material that they use, causing a higher exposure to glare (Fig 8 and 9).

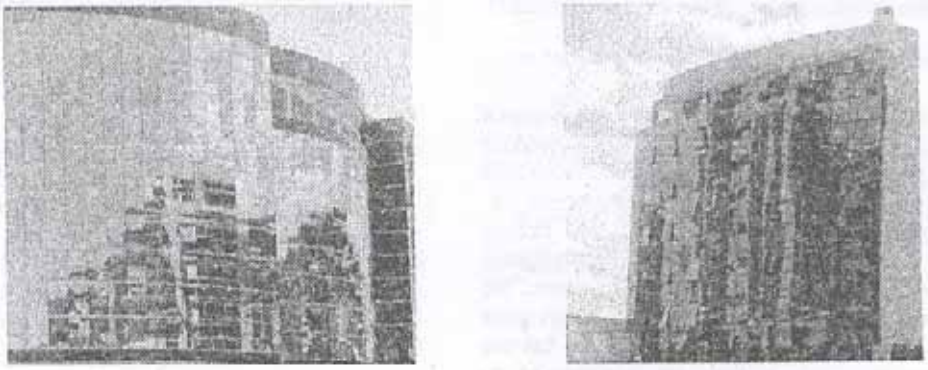

Figure 7 Sun and sky glare affecting buildings' materials

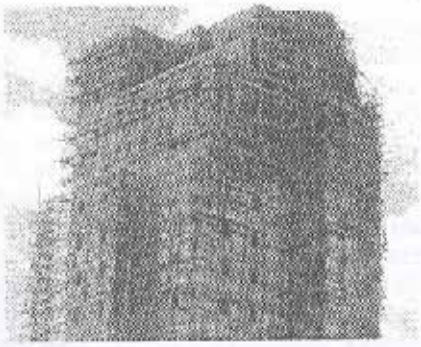

Figure 8 Glare affects contractors working on scaffolding of buildings with surface of glazing

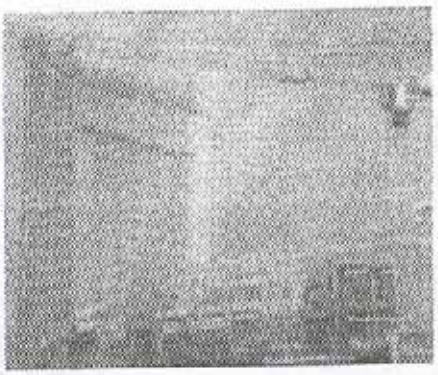

Figure 9 Patterned and recessed window glazing reduces glare effects

Sunlight consists of rays of various wavelengths. In the short wave range, it is the infrared rays that heat surfaces and dry the air; while ultraviolet rays have the ability to destroy bacteria." [22] During the daytime, the sunlight trespasses a room with different light intensities, according to its position on the sky. There are various angles of light coming from the sun, which have different effects on eyes. As observed earlier in this study, it is not the light itself that is so disturbing, but the angle from which it is propagated and orientation as well. This is what produces the glare effect.

In architecture, it is important to know and to identify the reflective materials, since they will be exposed to glare, creating the reflective glare. Moreover, it is of high importance also how buildings and spaces are perceived. Specialists consider that the "Choices of building materials and the locations of light sources can significantly transform the finished space from the design that had been conceived." [23]

Therefore, the materials used and light transform the spaces in their finished form that they were conceived in the design phase. This means that the architectural implementation will be adapted to the utilized resources and to the light that the building will benefit on. "Under certain conditions, light and reflections become modifiers of the "real" space, and reshape it into a different view that the observer actually sees." [24]

"A designer can spend any amount of time refining the layout of a space or spatial arrangement, the scale of a space, the materials and finishes of a space. However, with a few strokes, lighting can be added that will truly enhance or utterly destroy the desired effect." [25] Analyzing this approach, it can be observed that lighting plays a decorative role, which can create an entire atmosphere. Lighting is not just an architectural detail. It may be a detail for the user, but for the architects the lights are fully considered and thoroughly calculated within their designs and plans. The light's angles, its power, its structure, the effects that it creates, how the lighting affects the human eye, the utility of the light, all these and many other aspects are considered when planning the lighting system within a building.

From the architectural perspective, using natural lighting is more than an efficient solution for assuring natural light within the building. The natural light compliments the building, because it offers an aesthetical sense. Moreover, "Natural light in architecture must be part of a more general philosophy that reflects a more respectful, sensitive attitude in human beings towards the environment in which they live." [26]

For a sustainable environment, specialized studies recommend buildings constructions based on human activity relations: "The main habitable areas should be oriented to the minimum solar side, with perhaps the kitchen oriented to receive morning sun and the living spaces facing the after-noon and early evening sun, circulation spaces, bathrooms and garages can be situated on the non-solar side." [27]

Karlen and Benya discuss even about a residential lighting. They differentiate various types of buildings in describing the necessary and the recommended lighting system. Each space has its own lighting needs, depending on the functions that it required to accomplish. In terms of lighting, a residential building should be designed. "Residential spaces are usually personal and often intimate in their use, and their lighting design solutions should respond to that aspect of their function." [28]

CONCLUSION AND RECOMMENDATION

To mitigate the impact of glare pollution, there are different prevention measures which can be taken by different stakeholders with due attention. Some of the measures are stated below as the measure recommendations.

PREVENTION MEASURES

Sustainable Green Buildings

The sustainable environmentally friendly buildings, or the green buildings, are those constructions of which composition imply the environmental protection. Employing recycled/renewable construction materials, or durable and sustainable resources, for instance, are ways to contribute to the environmental sustainability, when designing a building. There have been developed a series of green technologies to be applied in the construction of the green buildings based on integrated design.

In the regions that utilize the natural resources for building houses, it is considered that a house, as its composing elements, has its own life. In the modern industries this aspect is also well recognized, as the building's life cycle. But unlike the modern industries, the traditional societies have a deeper understanding for a living house.

In the traditional regions, the basics of the construction techniques, the traditional technologies, and the usage of particular natural resources in building houses are inherited from generation to generation. People work together; help each other to build up a living space, and the entire communities collaborate.

Contrary to the traditional areas, the industrialized regions utilized a continuously growing number of resources, which are not produced from their close-by environment. The construction materials in the industrialized regions are manufactured products transported easily to different locations. The materials become continuously more diversified, that one may need special assistance in choosing the appropriate building materials.
With the construction need, the diversity of the materials increased, so did the costs of the materials and the toxicity caused by the building materials. In order to ensure the public safety, the environmental regulations, regarding the protection of the public safety also increased. However, despite the political planning authorities that impose sustainability regulations, the industrialized societies continue building, losing their knowledge of local building practices and self-reliance, unlike the traditional societies. [29]

Therefore, a strong and lasting building should be conceived from both, lasting materials, but it should also include easily replaceable products. Their recyclability must be considered ahead, since it is considered an efficient measure to reintegrate the materials that already passed through a life cycle, into new products. This minimizes the need of employing new natural resources, contributing to the environmental sustainability, by supporting the natural equilibrium. "Sustainable homes are sited, designed, and built so they are much less vulnerable to seasonal climate fluctuations than standard wood-frame houses. They fulfill the nearly universal dream of staying warm in winter and cool in summer.": [30] This is an encouraging perspective. The materials that compose a natural building are more close to the nature, since they are natural resources, and they respond different than the manufactured materials to the external factors.

Using sustainable resources reduces the environmental impact and protects public health. Because the sustainable resources are non-pollutant, people are less exposed to toxicity; hence, the illness caused by the construction materials is less likely to happen. Moreover, the natural buildings reduce the operating costs, because they will need less energy than the normal buildings. The green building's materials are designed to last longer than the normal buildings.

Technologies to Prevent the Glare

The positioning of the building is probably the most important aspect that should be considered, in order to ensure a good natural lighting in the interior of the building. However, both in residential and in non-residential spaces, there should be considered the correct positioning of the building so that all its interior spaces have access to the sunlight, during daytime. "Begin by planning the building such that every regularly occupied work or living space has access to a window, skylight, or other sources of natural light. Give high priority to windows that provide a view." [31]
There are modern types of windows utilized by the architects, planners and engineers nowadays, meant to prevent or to reduce the glazing: low-e glazing (Fig. 10). This is a type of window that is composed by two or more panes of glass. One pane is covered with a relatively clear material that is created to reflect the infrared energy while passing visible portions of the sun's energy.

Low-e glass is very useful and highly efficient in the buildings that utilize cooling systems in the hot weather, because it reduces the solar heat gains. Reflective coatings offer a mirrored aspect to the building, minimizing the building to absorb solar light and heat (see Fig. 11). Another type of glass, the tinted glass can minimize the solar penetration and reduce the glare (Fig. 12).

As Karlen and Benya indicate, the glazing selection is a compromise between clarity and energy efficiency. [32]

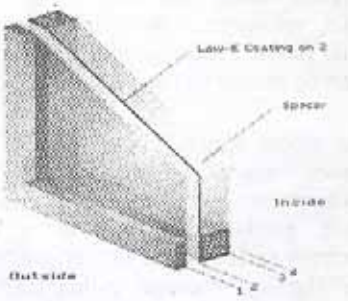

Figure 10 Low-e Glazing

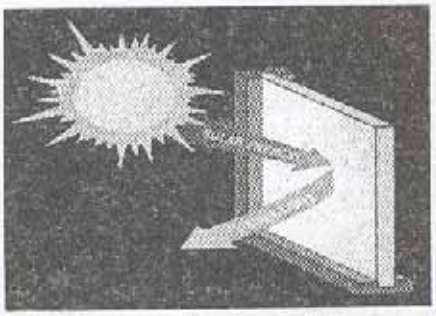

Figure 11 Reflected glass

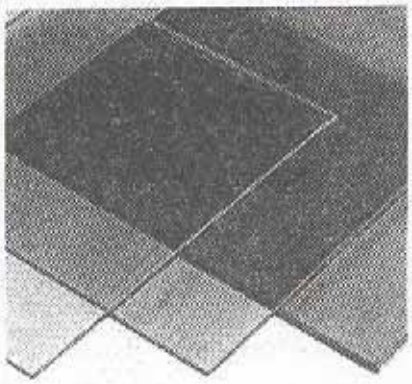

Figure 12 Tinted glass

In addition to this, by using the modern innovative technologies there can be created a top qualitative glass, by combination coatings and double coatings (Fig.13). There are different types of glass coating: the pyrolitic form or coating, embedding the performance coating during the float glass process, is usually utilized in the economical construction. Its colors and variety of coatings are limited. The sputter, also called the vacuum deposited, or the soft coating is the other form of coating. This one is available in multiple colors and types of coating, and is usually used in double glazed units, in order to achieve higher performances. [33]

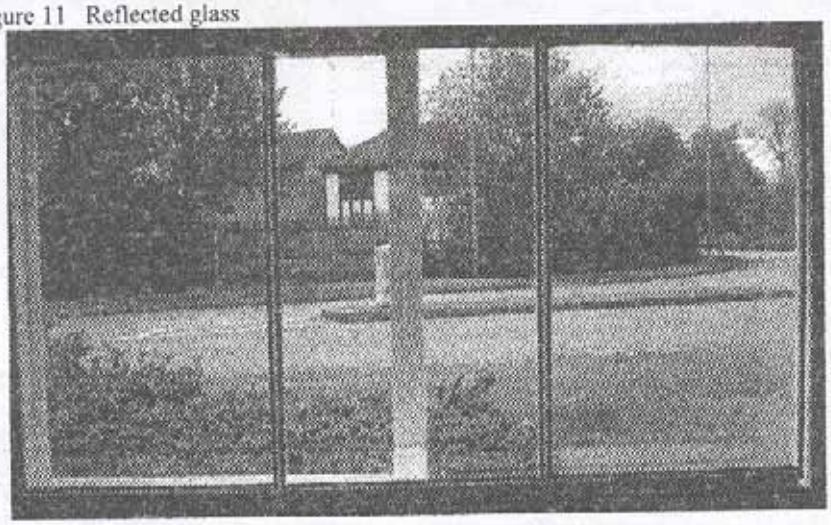

Figure 13 Double glazed glasses

ARCHITECTURAL AND ELECTRICAL ENGINEERING SOLUTIONS

The following are the reliable solutions to mitigate glare pollution:

1. Utilizing solid materials, which last longer, making the building more durable over time.

2. Adopting easily replaceable materials which should be environmentally friendly and reintegrated in other products, continuing to perform, within a new life cycle.

3. Using natural resources, without endangering the environment by abusing of these resources.

4. Designing buildings in such a way that they can obtain their natural lighting during the daytime, not being exposed to natural or reflected glare, light spills, or other forms of light pollution. Architects and engineers must be very careful to the specific location in which the buildings are constructed, and also, on the function that the buildings should accomplish.

5. Preventing the glare by utilizing vegetation. This can contribute to the reduction of heat gains also. Moreover, the vegetation can offer an aesthetic aspect to the building. Such solutions refer to planting trees around the building to prevent it from the ray lights, or even better, using green roofs. (Fig. 14) The performances of green roofs in saving energy, protecting buildings from sun and heat, saving heat losses during cold seasons, depend on their characteristics. The roof gardens are more efficient in reducing heat gains during summer times, than saving the heat during the winter times.

6. A special attention has to be given to the windows which represent the most efficient source of natural lighting within a building. However, the side effect is that they can also be the most powerful source for glare production. Their smooth, transparent surface allows the sunlight in and also the direct glare from the sunlight. Moreover, they can produce reflected glare upon other buildings from their vicinity. At the same time, accepting light in also leads to accepting heat in, since the light is a heat source also. For reducing these side effects, there are modern solutions for creating non reflective windows, but absorbing the natural light, preventing at the same time the heat gains.

7. Using shading systems and curtain wall for reducing glare pollution and the heat absorption.

8. Designing proper sun breakers to opening oriented to west.

9. Reducing the night time glare pollution by minimizing the artificial lighting and by properly using the outdoor lighting. Street polls, reflectors, outdoor advertising panels, other forms of light coming from buildings are creating serious damages to environment.

10. The proper lighting distribution in the living spaces and in the working spaces. In a working environment, where the glare effect can be easily produced because of a misplaced luminary or because of the reflected images of the lighting sources within the specular surfaces like using the application of two lamps, on either side of the desk. Like this, the shading surfaces are replaced with light and the light is reflected away from the worker's visual field. Also, as much as possible, the artificial light consumption in the indoor spaces should be reduced, by getting the light from the sun.

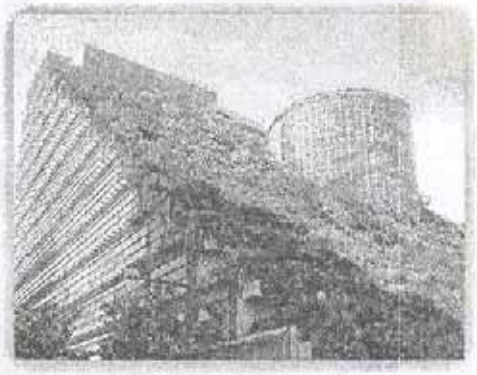

Figure 14 Roof gardens protect glare pollution

Legislative Measures

Policy makers/political actors and regulatory bodies have to design proper laws and regulation to mitigate glare pollution which owners of buildings, architects, planners and engineers are obliged to implement. International Glare Pollution Regulations can be the source to craft the regulation.

Capacity Building

Building the capacity of the professionals who are engaged in the sector is indispensable to mitigate glare pollution and to take professional measures. Senior and emerging architects, planners, engineers and associates should give and take training for proper delivery of environmentally friendly buildings. The private sector, professional associations, higher education institutes like EiABC, excellence centers like CeDC (Center for Excellence in Environment for Design, City Planning and Construction), have decisive role in conducting short, medium and long term training programs.

In general, architects, planners, engineers and designers should no longer ignore the needs of designing and constructing environment. They have professional responsibility to give due attention to green building/sustainable in each and every professional activities and to create awareness among their clients on environmentally friendly buildings. Regarding the lighting of the buildings, the regulations are expected to be oriented towards the outdoor lighting of the buildings. Political actors, construction companies, the environmental architects, planners and engineers should propose more environmentally sustainable solutions for creating solid, resistant buildings that abide by the need of the ecological system.

Based on this study, the proposed recommendations give emphasis on the necessity of further studies regarding the glare pollution, social responsibility and green buildings for environmental sustainability.

The first recommendation stresses on the vitality of further research in analyzing the relationship between all stakeholders those who fight for the environmental protection and the architects, planners, engineers, and contractors for preventing the light pollution. Together there is a need to train and educate people about the importance of minimizing their natural and artificial light consumption, in order to save the natural energy resources.

Second, in order to prevent glare pollution, it is recommended to explore the social responsibility campaigns to encourage people from all around to sustain the energy consumption reduction. The involvement of mass media in these environmental campaigns and research efforts will be a key resource to making awareness. It is also inevitable to explore the role of architects, planners and engineers the education/knowledge transfer of people regarding their social responsibility towards the environment, by recommending environmentally sustainable solutions that save as much energy as possible.

Finally, extensive research efforts to examine the use of natural resources, more long lasting (renewable) materials, starting from data collection, programming, concept development (inception), schematic, preliminary and final to working drawing and construction management. This study will help promoting green and sustainable buildings to the interest of the current attitude of humanity. The study shall also identify the legislative powers and political actors, medical professionals, senior and emerging architects, planners, engineers, associates and others responsible for efficient implementation of environmental architecture with focus on glare pollution avoidance of buildings.

REFERENCES

[1] National Cooperative Highway research program, NCHRP, (1999), pp. 33

[2] Carmeliet, J., H S. L. C. Hens, Vermeir, G (2003) Research in Building Physics: Proceedings of the 2nd International Conference on Building Physics, Lisse, Swets Publishers, pp. 396

[3] Schwarz, H. E. (Ed.) (2003) Light Pollution: The Global View. Kluwer Academic Publishers, Dordrecht, Wiley's. PP. 62

[4] National Cooperative Highway research program, NCHRP, (1999), PP. 33

[5] Narisada, K. Schreuder, D. (2004) Light pollution handbook, Volume 322, Norwell, Springer; and Shaflik, C, BASc, Peng (1997) Environmental Effects of Roadway Lighting. International Dark-Sky Association. Information Sheet 125.

[6] Narisada, K. Schreuder, D. (2004) Light pollution handbook, Volume 322, Norwell, Springer, pp. 295

[7] Narisada, K. Schreuder, D. (2004) Light pollution handbook, Volume 322, Norwell, Springer, pp. 295

[8] Narisada, K. Schreuder, D. (2004) Light pollution handbook, Volume 322, Norwell, Springer, pp. 296

[9] National Cooperative Highway research program, NCHRP, (1999), pp. 33

[10] Shaflik, C, BASc, Peng (1997) *Environmental Effects of Roadway Lighting.* International Dark-Sky Association. Information Sheet 125, pp. 10.

[11] Narisada, K. Schreuder, D. (2004) Light pollution handbook, Volume 322, Norwell, Springer, pp. 296.

[12] Givoni, B. (1998) Climate considerations in building and urban design, Toronto, Wiley's &Son. pp. 5

[13] National Cooperative Highway research program, NCHRP, (1999), pp. 33

[14] Narisada, K. Schreuder, D. (2004) Light pollution handbook, Volume 322, Norwell, Springer, pp. 301.

[15] Narisada, K. Schreuder, D. (2004) Light pollution handbook, Volume 322, Norwell, Springer, pp. 309.

[16] (Narisada and Schreuder, 2005, p. 314). Narisada, K. Schreuder, D. (2004) Light pollution handbook, Volume 322, Norwell, Springer, pp. 314.

[17] Eicker, U. (2001) Mitigation of nighttime construction noise, vibrations, and other nuisances, Leipzig, Wileys, pp. 291.

[18] Roaf, Sue, Roaf Susan, Crichton, D., Nicol, F. (2009) Adapting buildings and cities for climate change: a 21st century survival guide. Burlington: Elsevier, Ltd, pp. 246.

[19] Navara and Nelson, (2008) Environmental Health Perspectives, New York, Wiles, pp 140

[20] Roaf, Sue, Roaf Susan, Crichton, D., Nicol, F.(2009) Adapting buildings and cities for climate change: a 21st century survival guide. Burlington: Elsevier, Ltd, pp. 229.

[21] Gordon, G. (2003) Interior lighting for designers, New York, Wiley's, pp. 196.

[22] Santamouris, M. (2006) Environmental design of urban buildings: an integrated approach, Sterling, FSC, pp. 40.

[23] Michel, L (1995) Light: The Shape of Space: Designing with Space and Light, New York, Wiley's, pp. 45.

[24] Michel, L (1995) Light: The Shape of Space: Designing with Space and Light, New York, Wiley's, pp. 45.

[25] Russell, S. The Architecture Of Light: Architectural Light... (Perfect Paperback), La Jolla, Wiley's, pp. 17.

[26] Roaf, Sue, Roaf Susan, Crichton, D., Nicol, F.(2009) Adapting buildings and cities for climate change: a 21st century survival guide. Burlington: Elsevier, Ltd, pp. 116

[27] Santamouris, M. (2006) Environmental design of urban buildings: an integrated approach, Sterling, FSC, pp. 56.

[28] Karlen, M. Benya, J. (2003) Lighting design basics, New Jersey, Wiley's, pp. 73.

[29] Kennedy, J.F. (2004) Building without borders: sustainable construction for the global village, Ontario, New Society Publishers, pp. 7.

[30] Chris Maser (2009) Earth in our care: ecology, economy, and sustainability, New Jersey, Library of Congress, pp. 12.

[31] Karlen, M. Benya, J. (2003) Lighting design basics, New Jersey, Wiley's, pp. 35.

[32] Karlen, M. Benya, J. (2003) Lighting design basics, New Jersey, Wiley's, pp. 34

[33] Karlen, M. Benya, J. (2003) Lighting design basics, New Jersey, Wiley's, pp. 25.