# Role of Light in Green Technology

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**Abstract** Advancement of technology during past century has adversely affected the life-sustaining ecosystem of our planet by depleting natural resources and changing the global climate by carbon emission. This alarming situation has made the scientists aware of the necessity of mitigating or reversing the negative effects of human activities on environment. In the present discourse we propose to discuss various aspects of green or sustainable technology. Light or electromagnetic radiation plays a very important role in achieving green development of our economy and this forms the pivot of the present talk. In dealing with the uses of light and light-based technology on our ecosystem we must not overlook the dichotomy of light and dark. Darkness has also an important role to play in Green Technology. We propose to conclude by referring to the adverse effects of excessive, misdirected and obstructive artificial lighting, causing luminous pollution.

## 1 Introduction

The color green brings to mind the succulent green of grass, trees and forest. Green is veritably the color of Nature. Because of this association of green with Nature, it is often described as refreshing and tranquil color. In color psychology green is considered the color of balance, harmony and growth. Green relates to stability and endurance giving us persistence and strength to cope with adversity. In view of the above connotation of 'green', the technology that aims at the development of our society and economy without impairing ecological balance and that ensures sustenance is aptly called 'Green Technology'. Technological development during past century for maintaining our modern lifestyle has adversely affected the life-sustaining ecosystem of our planet. The accelerated consumption of fossil fuels and deforestation is monotonically increasing global temperature. We are exhausting our natural resources at a rapid pace and accelerating change in global

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I. Bhattacharya et al. (eds.), *Advances in Optical Science and Engineering*,
Springer Proceedings in Physics 194, DOI 10.1007/978-981-10-3908-9_9

climate that threatens our life-sustaining ecosystem and economy. Scientists have warned that if green-house gas emissions continue to increase we will soon pass threshold beyond which global warming would become catastrophic. Destroying environment any further can lead to a situation which can be irreversible. Thus the most urgent issue for present-day engineering and technology is sustainable development and reversal of negative effects of human activities on environment. During the last century we have acquired a huge amount of knowledge in various branches of technology. Mere knowledge however does not ensure sustainable development of our society and economy. What we need in addition is wisdom. In the context of green technology what we need may be called 'green wisdom'. Green technology is the technology endorsed by green wisdom. Green technology is intended to mitigate or reverse the adverse effects of human activities on the environment. It is developed and used in a way so that it does not disturb our environment and conserve natural resources. Green technology aims at sustainable development of our society and economy. Sustainable development is the development that meets the needs and aspirations of the society in ways that can continue indefinitely without damaging our environment or depleting natural resources. Thus, green technology or sustainable development ensures a better quality of life for everyone now and for generations to come.

## *1.1 The Sandestin Declaration*

In 2003 approximately 65 scientists and engineers from industry, academic institutes and government met at the Sandestin resort in Florida for a conference on 'Green Engineering: Defining Principles.' By the end of the conference the scientists collectively agreed to a compiled set of nine principles now known as the 'Sandestin declaration.' These principles are listed below: (1) Conserve and improve natural ecosystem while protecting human health and well-being. (2) Engineer processes and products holistically, use systems analysis, and integrate environmental impact assessment tools. (3) Use life-cycle thinking in all engineering activities. (4) Ensure that all materials and energy inputs and outputs are as inherently safe and benign as possible. (5) Minimize depletion of natural resources. (6) Strive to prevent waste. (7) Develop and apply engineering solutions while being cognizant of local geography, aspiration and culture. (8) Create engineering solutions beyond current and dominant technologies, improve, innovate and invent new technologies to achieve sustainability. (9) Actively engage communities and stockholders in development of engineering solutions.

In this context we talk of three R's of sustainable development: Reduce, Reuse and Recycle. In order to ensure sustainable development we must try to reduce the use of natural resources as much as possible. We must also make efforts to use fewer materials so that we produce less waste. Besides, one must not throw away acceptable and reusable materials. Recycling of these materials is an important factor in conserving material resources.

## 2 Different Kinds of Green Technology

A technology endorsed by 'green wisdom' belongs to the field of Green Technology. Needless to mention that all branches of technology that take into account the imperatives dictated by green wisdom belong to green technology. Thus, green chemical technology is green counterpart of chemical technology; green electronics is the green counterpart of electronics and so on. The other kinds of green technologies include green energy technology, green information technology, green photonics, green lighting technology, green manufacturing technology, green building technology, green nanotechnology etc.

### *2.1 Green Chemical Technology*

Green or sustainable chemical technology is based on a philosophy of chemical research and engineering that encourages the design of products and processes that minimize the use and generation of hazardous substances. Besides, it focuses on technological approaches to preventing pollution and reducing consumption of non-renewable resources. The most important green chemical reaction is photosynthesis. In this reaction carbohydrates and oxygen are synthesized from carbon dioxide and water in presence of sunlight. According to Genesis, light was created at the very beginning of the creation of the universe. It could not be otherwise because light happens to be the prerequisite for sustenance of life. Photosynthesis that sustains life is the first green technology on our planet.

### *2.2 Biomimicry*

Biomimicry is a new discipline that studies Nature's design and processes and imitates them to solve human problems. One of the examples of biomimicry was the study of bird to enable human flight. Leonardo da Vinci (1452–1519) closely observed the anatomy and flight of birds and made various notes on the possibility of creating a heavier-than-air flying machine. Again, studying the structure of plant leaves enabled the scientists to invent a better solar cell. It is observed that plant leaves have wrinkles and folds. Imitating this structure of leaves, scientists of Princeton University, headed by Prof. Stephen Chou, were able to achieve major gains in light absorption and efficiency of the solar cells. They showed that the efficiency of solar cells can be increased considerably by using a nano-structured 'sandwich' of metal and plastic that collects and traps light. Prof. Stephen Chou and his team used nano-technology to overcome two main challenges that cause solar cell to lose energy—(1) light reflecting from the cell and (2) the inability of the cell to fully capture the light that enter the cell. The efficiency of solar cells has been

considerably improved by using metal nano-particles in plasmonic solar cells and nano-particles of semiconducting materials in quantum dot solar cells.

## 2.3 Artificial Photosynthesis

Artificial photosynthesis is a chemical process that replicates the natural process of photosynthesis. Artificial photosynthesis is more versatile in its scope in sense that it is not just the formation of carbohydrates and oxygen from carbon dioxide and water using sunlight. Artificial photosynthesis system or photochemical cell that mimics what happens in plants could potentially create an endless supply of clean energy. Artificial photosynthesis is essentially leaf-mimicking. Photosynthesis is essentially two half-reactions of oxidation and reduction. In natural photosynthesis water molecules are photo-oxidized to release oxygen and protons. The second part of the reaction is a light-independent reaction that converts carbon dioxide into glucose. Researchers working on artificial photosynthesis are developing photo-catalysts that are able to perform both the reactions. By using photo-electrode in which gold nano-particles are loaded on an oxide semiconductor substrate, research at Hokkaido University, Japan, has worked to develop a method of artificial photosynthesis for successful synthesis of ammonia using visible light, water and atmospheric nitrogen.

## 2.4 Green Energy Technology

Green energy technology is very important branch of green technology. The global power sector is the biggest pollutant of our planet. It generates 40% of all global electricity from coal contributing most significant amount of green house gases that adversely affect global climate. According to the International Energy Agency, the power sector is responsible for 37% of carbon emission. Green energy technology therefore shares a big responsibility in producing clean energy for sustainable development. Photonic s or light-based technology plays important role in generating renewable energy without impairing our environment. The most promising source of green energy is the Sun. Green energy technology studies and develops optical systems for generating renewable energy. This includes solar cells and photovoltaic devices creating energy-efficient optical sources.

Solar or photovoltaic cells convert solar energy into electrical energy. These cells are based on photoelectric effect: ability of matter to emit electrons when irradiated by light. Silicon is a key ingredient in solar cells. As solar light hits silicon atoms they transfer their energy to dislodge electrons of the atoms that drive the current through the cell.

## 3 Lighting Technology

One of the outstanding inventions in lighting technology is LEDs of very high luminous efficacy. We may recall that the luminous efficiency of incandescent lamps is only about 12 lm/W and that of tungsten-halogen lamps is only about 18 lm/W. Thanks to the development of blue LEDs, the luminous efficacy of white LEDs with phosphorescent color mixing is as high as 260–300 lm/W.

Three Japanese scientists, Isamu Akasaki, Hirosi Amano, and Shuji Nakamura were awarded 2014 Nobel Prize in physics for their invention of blue LEDs. Some researchers at the University of Hiroshima in Japan have used silicon-based quantum-dots for a type of LED that promises to revolutionize lighting system. Japanese researchers have fabricated a hybrid organic/inorganic LED that produces white-blue electroluminescence using quantum dots. An organic LED is a device in which emissive electroluminescent layer is a film of organic compound that emits light in response to electric current.

### *3.1 Light Pollution*

We hear a lot of discussion about air pollution, water pollution, sound pollution etc. Because of the artificial illumination of high level, particularly in urban areas during night, a new kind of pollution, known as light pollution, has become a matter of grave concern for biosphere of our planet. Light pollution, also known as photo-pollution or luminous pollution, is caused by excessive misdirected and obstructive artificial light. It is the result of outdoor lighting that is not properly shielded, allowing light to be directed into the eye and the night sky. As excessive sound causes sound pollution so also excess light causes light pollution. Light that shines into the eye is called ‘glare’ and light shining into the night sky above the horizon causes ‘sky glow’. The other major component of light pollution is ‘light trespass’. Urban sky glow is caused by brightening of night sky over inhabited areas, light trespass is light on areas where it is not intended or needed and glare is the excessive brightness that causes visual discomfort.

There are many adverse consequences of light pollution some of which are listed below: (1) It disrupts ecosystem. (2) It poses serious threat to nocturnal wild life. (3) It has negative impact on plant and animal physiology. (4) It can confuse the migratory patterns of animals and alter the competitive interaction of animals. (5) It can change predator –prey relationship. (6) Light pollution has devastating effects on many bird species. Birds that migrate at night navigate by moonlight and starlight. Artificial light can cause them wonder off towards the dangerous night-time landscapes of cities. (7) Every year millions of birds die colliding with needlessly illuminated building. Artificial light can cause them to migrate too early or too late and miss ideal climate conditions for nesting, foraging and other

behavior. (8) Many insects are drawn to light. Artificial light can create fatal attraction and decrease insect population. (9) Declining insect populations have negative impact on species that rely on insects for food or pollination. (10) Some predators exploit this attraction to their benefit, affecting food webs in an unanticipated manner. (11) Artificial light near sea beach has devastating effects on sea turtles. These turtles live in sea water. When mature female turtles are ready to lay eggs they come to sandy beach and find a suitable dark place for the purpose. They dig shallow holes in the sandy beach with the help of their hind limbs and bury their eggs in these holes. After an incubation period of about eight weeks the eggs are hatched. However, the hatchlings stay under the sand until temperature and other conditions are right for the baby turtles to come out of the sand and move to the sea with the help of moonlight reflected from the sea. The presence of artificial lights from houses near beach, car parks and security light deceives baby turtles and disorients them. Consequently, they fail to reach the sea and move towards the artificially illuminated regions. Many of them die or get killed before they find the way to

## 4 Epilogue

From above considerations it is evident that light-based technologies have promising potentials to be green, smart, life-sustaining at the same time. Light, that played a vital role in originating life on earth, bears promise of ensuring sustenance of entire biosphere. This ethereal angel stands as a protector and savior of life in all its forms. Light has created many wonders that substantially contributed to green development of our technology. We are yet to explore various possibilities of photonic technologies for generating renewable energy, and for reducing energy consumption and green-house gas emission. ‘Life throws challenges and every challenge comes with rainbows and lights to conquer it.’ (Amit Ray, World Peace: The Voice of a Mountain Bird). If we ignore the figurative meanings of the words ‘rainbows’ and ‘lights’, the above quote may be interpreted to imply that light with all its variegations bears the promise of solving any human problem.

However, it is not the responsibility of the photonic technologists alone to keep our Mother Earth clean and life-sustaining. Herbert Marshal McLuhan, a Canadian Professor of English and an expert of mass communication, once said: ‘There are no passengers on spaceship Earth. We are all crew.’ Prof. McLuhan implied that all of us, irrespective of our nationality, religion and creed, are equally responsible for keeping our planet life-sustaining and healthy abode for all living creatures.