**Theme: Nature Based Solutions to Climate Change**

# Solar, Biomimicry and Sustainability

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## Abstract

The world at present is experiencing the effects of unnatural growth, lack of nature at macro planning and design, and fossil fuels spewing in the atmosphere. These problems have been created due to various individuals, and groups at professional, government, administrative and even educational levels not adequately exposed or feeling, and understanding nature. Our existence is due to the sun energy and everything else comes from that initial atmospheric balance. We need to study how we can quickly turn the energy consumption to clean energy mainly solar and wind and the new emerging cleaner renewables. The paper will look at various such initiatives across the world, the positives and drawbacks experienced, and the way forward. We humans need to closely study and look at the natural world and their dwellings from the pagoda ant nest to birds and butterflies see how they use light, wind and colour and look at their way of consumption. The paper will bring out the biomimicry adaptations and possibility of future housing and work designs.

The author has experience in nature related education with groups, and also community development due to professional and community work. The insights gained by studies, courses field work, field visits to forests and local communities will be incorporated and analyzed. The Sustainable development goals (SDGs) 13,14 and 15 have several indicators that lead to action, most important being climate action.

The paper will bring out the fascinating situation of the city of Mumbai. At micro level of a coastal city like Mumbai, a large fishing population whose livelihood depends on the sea, and at the same time has the only forest in the world that can be reached within minutes or hours by the citizens. We have most tech savvy population but hardly any blend of the two. The paper will bring out how technology can be used for nature awareness and bonding children, and youth to the wonders of nature. What are the means to bring about sustainable consumption and save the natural endowments of a place for the future generations.

## Introduction

I have been inspired by the idea and thought of solar energy ever since I was introduced to the fascinating solar facts during my climate change training and earlier during nature walks, watching the amazing hues of various colours, the result of photosynthesis by leaves in nature. The forest in Mumbai is of southern moist deciduous type. In deciduous forests, majority of canopy trees shed their leaves in winter, summer sees some plants flowering and fruiting and monsoon transforms the forest with its very first showers. Herbs and wild flowers of various hues and colours sprout and fade away only to be replaced by more fascinating ones. The forest comes alive, the streams provide rich aquatic life, and the forest is in its true full colours (Atthar, 2011).

In Mumbai forest one encounters architectural marvels every few steps, one such is the tiny termite mound, *Termes obesus*, the high tech, self–sufficient marvel built by soil dwelling tiny termites. The mound has various walkways and chambers laid inside with vents for steady temperature maintenance and a nursery, fungus garden, all created with orderly division of labour. Termites are blind from birth, and lack individual intelligence and yet as a community they are brilliant builders. Together with ants, bees and wasps they belong to a group of insects which form colonies and their behaviour is fascinating researchers. A few steps ahead one encounters the signature spider weaving its signature into the billions of years old architecture, a fascinating sight and little ahead is the Harvester ant *Pheidole Sp*. master circular architecture, to ensure proper drainage and protect the nest. Walk a little ahead and you think a chandelier is stuck in the leaves, it turns out to be a paper wasp *Polistes hebraeu*, nature's paper making technology. Trees with lichen an indicator of good oxygen levels, are seen in this well-established ecosystem and some evergreens like the football tree *Morinda pubescens* add to the charm and diversity of species seen. The varied birds with their unique nest building abilities, and colours and preferences of food makes one wonder at the intelligence in nature, and how everything falls in place. The rhythms of seasonal changes, the balance in a dynamic ecosystem. The circular economy at its best with beautiful fungus growing on dead wood, and the myriad insects in the leaf litter closing the loop in nature.

**Sun**

Research shows that there is enough sunlight that falls on earth in one hour to fulfill the energy needs of the whole world for one year. It is strange that we humans have been so focused on extraction from the earth, more so since the industrialization age, that the natural solutions have been overlooked till recently, and in the process destroyed the habitats of millions of creatures.

But what is our life-giving star sun made of? Let us get to know more details.

Initially it was thought that our sun was just one giant ball of fire, burning like a candle. This theory did not hold good due to the fact that if it was burning, it would have not been existing for millions of years. Another theory was that the sun's huge gravitational pull, due to its large mass, was being converted into energy. This theory did not account for the age of the sun which must be more than 4.6 billion years old, the age of the oldest known rocks on earth.

The German scientist Albert Einstein solved the mystery at the beginning of the twentieth century, by providing the answer with his formula $E=mc^2$, where E is energy, m is mass and c is the speed of light. In the sun hydrogen nuclei collide with one another to create helium atoms. In this process, called fusion, mass is transferred into energy. This process will continue for millions of years until the last of the hydrogen in the sun is used up (Duncan, 2008).

The bright white disc that appears in the sky is the layer of the sun called the photosphere. The photosphere is the surface of the sun which emits the visible light that we see here on earth. The solar atmosphere is divided into three layers. The chromosphere, the transitional zone, and the corona. All three are outshone by the photosphere and so can only be observed as visible light during a solar eclipse. Beneath the photosphere is the sun's interior. The sun's core undergoes such intense heat and pressure that the process of fusion is unremittingly generated. Surrounding the core is the radiating zone. Photons emitted from the core in the process of fusion collide with ions in this layer and transfer small amounts of energy (Duncan, 2008).

A solar cycle occurs every eleven years, when the sun is most active. At this time known as solar maximum, more than one hundred sunspots can be seen whereas none can be seen during the sun minimum. Auroras also increase in frequency when the sun is at its period of maximum activity.

The making of an aurora is due to the particles and magnetism between the Sun and Earth. Solar wind is produced by the sun made of charged particles called plasma carrying the Sun's magnetic field. As the solar wind nears the Earth's surface it causes the magnetic field of the Earth to be drawn into a giant teardrop shape, squashed on the side closest to the sun and drawn out into a long tail on the side farthest from the sun. This giant magnetic bubble is called the magnetosphere (NASA).

The largest geomagnetic storm of recorded history, the Carrington Event, occurred in 1859. This storm was so big that it lit up the skies with aurora from the poles to the tropics. Electrical currents from the storm caused sparks and fires in telegraph system and disrupted communications. Although very rare, experts have indicated that impact of a Carrington -like event in present times could be worst then the worst natural disasters human have faced so far (NASA).

We have come a long way from regarding solar energy as very expensive and unfeasible, to having affordable solar panels and batteries at present. The price of solar has gone down as compared to fossil fuels, and more and more of the energy needs are being met around the world by renewable energy. However, policy level implementation is poor and therefore even those population who want to switch to renewable energy are not able to do so due to lack of service and, other connectivity and availability issues. This is particularly acute in solar rich countries like India where the heavy transport vehicles, and cars continue to spew poison into the atmosphere with diesel and petrol vehicles being sold with glamorous advertisements. Due to unsustainable usage of air conditioning and also continued use of fossil fuels the carbon dioxide in the atmosphere is way above the 350ppm which is the upper limit to maintain the balance. Along with this is the methane, water vapor and other greenhouse gases that are causing extreme climate events around the world.

**Biomimicry**

As a long time, student of sustainable development and having written research papers on sustainable development and related areas with my passion for nature, I gravitated to study Botany and Ornithology along with plants interactions. Fortunately, I got an opportunity to observe and study a plot of forest in my city with a leading conservation NGO of India as an activity and also do citizen science. The courses took me to different forests and habitats and I could integrate my social sciences knowledge with learnings from the natural world. But there was something missing and that was the application part in tangible form to our daily lives. As I was thinking of how to further integrate all my different strands of academia what dawned on me was the relevance of biomimicry. This was a question in my mind during my various nature walks and particularly when with school children who would be thrilled when shown the various facets of nature and equally gleeful when they would see an Orchid Mantis,*Gongylus gongyloides* which has leaf patterns on its gait to camouflage, or a pond scater*, Gerris sp*. seen in water bodies, a long legged aquatic predatory bug seen 'skating' over the ponds without breaking the water surface. Pagoda Ant *Crematogaster dohr,* built on tree tops by red ants who guard their nests ferociously. It's made of bark paste prepared by the ants. All this and much more whilst going

through the forest track. Once in seven years comes the delight of the purple karvi blooms *Strobilanthes callosus* whose dried stalks are used by the local Warli tribes as their dwelling, again an ingenious form of architecture that has insulation to keep it cool during summer and warm during winter, learned and implemented from nature over many generations. During monsoon listening to the pumping noise of water in a huge tree with a white bark *Sterculia urens* also called a ghost tree due to its white bark which appears as a ghost in the night forest, was nature's intelligent pumping technology at display, and the water cycle. The nitrogen fixation of the soil and the plants that monkeys choose to eat made it obvious that primates were all nutritionists who knew exactly what to consume and what not to consume. Touch, feel of the textures, smell of leaves and its properties and various attributes, make these walks rich open class rooms where the 3.8 billion years of research and development of the natural world can be studied first hand! This is simply stated by Rachel Carson as *"In nature Nothing exists alone."*

E.O. Wilson in his classic book *Biophilia* said "The elements from which a deep conservation ethic might be constructed include the impulses and biased forms of learning loosely classified as biophilia. Ranging from awe of the serpent to the idealization of the savanna and the hunter's mystique, and undoubtedly including others yet to be explored, they are the poles toward which the developing mind most comfortably moves. And as the mind moves, picking its way through the vast number of choices made during a lifetime, it grows into a form true to its long, unique evolutionary history" (Wilson, E. O. p.139)

In our closed earth system only, sunlight comes from outside and occasionally the asteroids, so the balance is well evolved and systems are in place. I was as thrilled as the students when I got to know about this field and reading the pioneer in the field Dr Janine Benyus's book on Biomimicry.

Biomimicry is an approach to innovation that seeks sustainable solutions to human challenges by emulating nature's time-tested patterns and strategies (Benyus:1997)

According to Janine Benyus there are nine basic principles the strategies, natural laws that are employed by nature, understanding of which will enable practical application. 1) Nature runs on sunlight 2) Nature uses only the energy it needs 3) Nature fits form to function 4) Nature recycles everything 5) Nature rewards cooperation 6) Nature banks on diversity 7) Nature demands local expertise 8) Nature curbs excesses from within 9) Nature taps the power of limits.

Explaining about form to Function Benyus (1997) states as follows "shell of a sea creature called an abalone is twice as tough as our high-tech ceramics. Spider silk, ounce for ounce, is five times stronger than steel. Mussel adhesive works underwater and sticks to anything, even without a primer. Rhino horn manages to repair itself, though it contains no living cells. Bone, wood, skin, tusks, antlers, and heart muscle—miracle materials all—are made to live out their useful life and then to fade back, to be reabsorbed by another kind of life through the grand cycle of death and renewal."

The author further states "The rhinos, mussels, and spiders in the slides all seemed to be wearing Mona Lisa smiles. Somehow, out of the world's most common chemicals, like carbon, calcium, water, and phosphate, they fashion the world's most complex materials (Benyus, J. p.97-98).

"In nature, shape is synonymous with function. Proteins start out as strings of amino acids or nucleotides, but they don't stay that way for long. They fold up in very specific ways", (Benyus: p. 203)

Flight of birds inspired Leonardo da Vinci's flying machine and the Wright brothers to make the first prototype of their airplane. A significant example of design by adaptation from birds in modern world is the bullet train of Japan, Shinkansen which was giving a sonic boom noise whilst emerging from tunnel and was modified after the kingfisher's beak who dives into water without a splash. The train engineer was a bird watcher and after studying the bird emulated the diving technique in water to solve the noise problem.

Another significant emulation from nature's function and design is Velcro which was inspired by tiny hooks on the burdock seeds first used by NASA, and now widely used in sports, shoes and many other products.

In Harare Zimbabwe termite mound inspired the East Gate Centre building and there was substantial decrease in energy used in this building as compared to similar buildings in Zimbabwe. It has become a landmark in sustainability.

The most wonderful green house in the world is the Eden design at Cornwall. Eden at Cornwall is an example of biomimicry and how a clay pit was converted into very unique forest biomes of rainforest and Mediterranean, the design used the soap bubbles which most of us would have played with as children. True to the definition of the term 'biomimicry' which describes the process of humans borrowing designs and systems from nature to create their own technology, the architects of Eden at Cornwall used opposing spirals mathematically based on Fibonacci's sequence (0, 1, 1, 2, 3, 5, 8, 13…) where every number is the sum of the previous two. The spirals on a pinecone, pineapple and sunflower, like the Core roof, usually represent two consecutive numbers in this sequence. The weight of the structure of Biomes is less than the weight of air inside! (Eden project,Cornwall)

**Photosynthesis**: During my study of forest and nature walks I have been completely enamoured by the foliage colours of trees like bronze, copper, orange, pinks and its combinations, yellow, reds and purples of trees like yellow silk cotton *Cochlospermum religiosum* or kusum *Schleichera oleosa*, as delightful as the colours of butterflies and peacock feather which are structural and uses light to create colours. In leaves how does this occur? We are familiar with the fact that green pigment in plant cells-chlorophylls– absorb energy from sunlight. The primary function of pigments in plants is photosynthesis, the most important process of life on earth, in which the green pigment chlorophyll along with several red and yellow pigments help to capture as much light energy as possible. The light that is absorbed is used by the plant to power chemical reactions, while the reflected wavelengths of light determine the colour of the pigment that appear to the eye. It is the combination of the other pigments present that give the leaves these spectacular colours (Atthar, R. 2011)

However as mentioned by Professor Jeffrey Sachs in his Book *Age of Sustainable Development* homo sapiens are consuming this natural resource far more than is our share on this planet

"Humanity is now taking as much as 40–50 percent of all of the photosynthesis on the planet. We are commandeering the world's basic food supply—the output of photosynthesis—not for all species, but only for ourselves. It's like inviting 10 million guests (the roughly 10 million species on the planet) to a banquet, and then announcing that half of the food supply will go to just one of the guests, Homo sapiens" (Sach, J.D. p. 456).

Within this high usage of photosynthesis there is too much of inequality with poor farmers and marginal farmers being pushed into a spiral of debts and poverty making the food prices rise

leading to malnutrition and health issues in developing world, and amongst the poor in the developed world. Added to this situation is the threat of major companies trying to monopolize seeds, and lead to monocultures, wiping out the rich diversity of different varieties of grains and vegetables and consequently affecting soil health.

**Sustainability**

The natural world has evolved over billions of years and some of the functions and processes have been perfected over such a large period which we humans grapple with, or is still a mystery for us. The Paris Agreement Art. 5 recognizes the key role forests play in limiting global warming.

Co-evolution of species is one of the basic elements of evolution. One of the most fascinating complex features of mutualistic co-evolution is between ants and the species Acacia tree *(Mimosoidea, Leguminosae*). Acacias are elegant trees with pinnate leaves divided into many rounded leaflets along a central vein. The relationship between ant *Pseudomyrmex ferruginea* and the tree *Acacia cornigera* is as follows-The queen ant lands on a swollen stipule and cuts a hole in it; she clears out the parenchyma to leave a hollow cavity to lay her eggs. The plant provides her the food by secreting nectar from special glands, called foliar nectaries which are at the base of the leaves. The queen also gathers small swollen nodules from the ends of the pinnae of the leaves. These modified leaf tips are called Beltian bodies and contain proteins and lipids. The queen feeds its developing larvae and a colony of ants develops. Around 1200 worker ants would be living in various swollen stipules on the tree within a month and in few years' time there can be as many as 30,000 ants in the colony. These numerous workers swarm all over the acacia tree attacking insects and other herbivores that come their way They also attack any plants which come in contact with their acacia. They even clear the ground of plants under the tree, leaving a bare circle up to a meter in diameter around the trunk. If acacias have their ants removed, they are destroyed in a year or two by insects and other herbivores and vines. With such protection from the ant colony, the acacia does not need any expensive structural or biochemical protection mechanism. The energy conserved by the tree is used by the tree in making swollen stipules, nectar and Beltian bodies to house and feed the ants. The benefits to this co-evolutionary relationship far outweighs the costs (Chapman & Reiss, 1995).

At present research is being done on bees and ants and how they use minimal energy to take nectar. Appliances can be made to communicate like them to conserve energy. Mycorrhizal network sustains diversity in a forest by transporting nutrients and water.

Examples of Biomimicry where renewable energy technology is improved upon are several.

Leaves gather energy and turn it into chemistry. A group at Smit was inspired by the Ivy climber and made Solar Ivy. The Ivy climber inspired this group to emulate the adaptability of the climber, they can shape the climbers and so the team emulated this to solar collecting mechanism that can be attached to different shapes instead of flat square shape panels. Further they also emulated the way the leaves rustle in the natural world, and designed the solar leaves so as to collect the kinetic energy into stems to create the effect and the sun energy for solar power.

Tubercle technology by innovator Frank E. Fish, who observed the humpback whale flippers which have tubercles or bumps which leads to best possible water flow. His further research and insights lead to the more efficient wind turbines by harvesting currents in the wind.

Almost the entire world is signatory to the United Nations (UN) Paris agreement on climate change in 2015 and the adoption of 17 Sustainable Development Goals (SDGs) by the UN in 2015. To meet the target of keeping the global warming below 1.5 degree Celsius as compared to the pre – industrial stage. Countries have to cut down their carbon emissions and other greenhouse gases and adopt renewable energy in a major way. Taking stock of how the countries have fared so far, the Stockholm report has indicated some key findings

The strongest links between the nationally determined contributions (NDCs), and the SDGs are found in the areas of water, food and energy.

However, not all environmental SDGs are equally reflected in the NDC commitments. For example, there are four times fewer activities related to SDG 14: Life Below Water than SDG 15: Life on Land. The social SDGs are highly under-represented in NDC commitments compared to the environmental and economic goals; in particular health, education and gender equality (SDGs 3, 4 and 5, respectively). The NDCs clearly reinforce the interlinked character of sustainable development. Several SDG themes (i.e. socio-economic sectoral categories) are addressed by numerous climate actions, indicating that there are multiple potential synergies and opportunities for policy coherence, (Dzebo, A. et al).

More than 70% of NDCs include forests as planned contribution to climate change mitigation and adaptation. But since these are not legally binding, the old growth forests which are superior for water and soil conservation than new forests are being hacked in the name of infrastructure and development projects.

**Ocean and Climate Change**

In June 2017, the United Nations (UN) held its first Ocean Conference, during which UN member states gathered to discuss how to best achieve UN SDG 14, which is to conserve and sustainably use the oceans, seas and marine resources for sustainable development. Ecological concerns on the conference's agenda included the restoration of coastal and maritime ecosystems impacted by climate change as well as reducing the acidification of the ocean. Acidification threatens many species of marine life and occurs when the ocean absorbs a surplus of carbon dioxide. Member states also discussed how to use policy to respond more effectively to maritime issues and ensure that the benefits and responsibilities of using the ocean are distributed fairly among them.

Mumbai is a coastal city and it is in the top ten cities around the world threatened by sea level rise in terms of population that will be affected, and the assets loss if sea water floods the city.

The monsoon rains in Mumbai is already very erratic with very heavy downpours in few hours as seen this season too, flooding the entire city and long dry spells. Added to the woes is the rampant tree cutting and constructions all over the city. The new building model is towers and they have fewer open spaces and toxic air, with lots of air conditioning. Glass façade buildings a completely wrong design and material for Mumbai's climate is used quite a lot in suburbs of Mumbai especially for corporate buildings and one recent new business school.

Compared to the above is the ancient architecture of India starting from Indus valley civilization where there was proper drainage and water systems and was a flourishing civilization. Many of the forts and living dwellings of the earlier periods had well laid out gardens and designs where wind and light was freely flowing and water harvesting and reuse was inlaid.

Studies have shown the ocean to be a useful barometer of climate change. Exchanges of heat and greenhouse gases between the ocean and the atmosphere help regulate climate and weather. The ocean becomes hotter when it absorbs more heat and then releases this heat back into the atmosphere. Scientists have determined that the ocean has absorbed more than 90 percent of the increased heat caused by the rise in carbon dioxide (CO2) emissions and other human activities since the 1970s. Shifts in temperature can disrupt hurricane seasons, leading to more powerful and destructive storms. The oceans absorption of increased amounts of heat and CO2 has also impacted its chemistry, raising concerns about the acidification of the ocean. Acidification occurs when the increased CO2 decreases the pH level of ocean water, which can reduce the presence of calcium carbonate minerals that are vital for marine life. This also affects the coral. Heat absorbed by the ocean also results in the thermal expansion of seawater molecules and travels to the planets poles, causing glaciers and ice sheets to melt and sea levels to rise (Gale, 2017).

The ocean health is also very important because of the fact that biological mechanisms are based on plankton, making up 95% of marine biomass; phytoplankton, on the ocean surface. This acts like forests on land, as it absorbs carbon dioxide. Through photosynthesis it produces 50% of the oxygen we breathe.

**Conclusion**

The ecosystems in nature are sustainable and have circular loop. There is no waste and no pollution in natural processes. Something that happens with regularity in a linear economy. A major change in consumption patterns, and behavioral changes need to be adopted by homo sapiens to reduce climate change.

The designs of various products using technology following the principles and methods of Biomimicry can lead to sustainable and ecological buildings and the city ecosystem. However, this will be possible if there is integration of various subjects, nature connectedness and learners who can ask the relevant ‘how’ questions, and find the answers in the biological models. Context and systems approach, deep grasp of the related subjects in social sciences, and guided by the SDGs along with nature inspired teams.

Tipping elements are the most vulnerable components of the Earth System and as researchers have called them “the Achilles heals of the Earth System”. They are the large-scale components of the Earth System that may pass a tipping point and change state. With rising temperatures, these elements are the first to either change or disappear. Those processes are potentially irreversible (Schellnhuber, J. 2009).

The thin layer of atmosphere over our earth is of 15 degree Celsius, just right for life to flourish. Solar energy harnessed through renewable energy, application of biomimicry principles and emulation, interconnectedness and interlinking of SDGs is the way forward to save our earth, ecosystems and various species on the planet along with homo sapiens.

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