

# Exploring the Applications of Bio-Eco Architecture for Sustainable Design and Construction process

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## **ABSTRACT:**

It has been commonly noted that the main perception of nature influenced forms is basically aesthetic while little concern is given to the importance of inspiring from nature in the construction and structural performance of buildings as well as in the natural ecological architectural solutions, thus, this paper will focus on bio-inspired architecture approach which embraces the eco-friendly practices of sustainable construction, the use of natural materials and the energy conservation by mimicking the natural life.

A number of bio-inspired architectural designs will be illustrated presenting a comprehensive analysis of bio-inspired role to be played in developing the concept of ecological sustainable design and construction in contemporary architecture.

Building must teach the society with new ecological moral, thus, a better understanding of biological morphogenesis can usefully inspire architectural design to resolve challenges that have already been resolved by nature that will not only help in creating a healthy environment but will also produce positive environmental impacts.

Bio-Eco Architecture harnesses and replicates the principles found in nature in order to create built environment which benefit people and other living creatures as well as safeguarding the biodiversity; thus, Biomimetics in architecture will help develop a culture of active environmental design.

*Keywords:* ecological design, natural environment, Energy

## **1. Introduction:**

Since the energy crisis in the 1970, the ecological design movement is concerned with energy efficiency and the influence of building on the surrounding natural environment. At the cutting-edge of contemporary architecture, there have been many new directions during the 21st Century, but three stand out: height, sustainability, and bio-inspired designs; thus, a new balance will be struck between scientific-technological advancement and human development(emergence of bio-architecture and eco-technologies) to connect

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the old vision of ecological design with the contemporary one of biological inspiration.

The new approach carried out in this paper transfers the biological characteristics of natural life on the built environment. The study of the overlapping fields of biology and architecture will show innovative potentials for architectural solutions which help reducing the harmful effects of building industry on the environment.

This paper will focus on bio-inspired architectural design which achieves sustainable and ecological design. The central canon of Bio-Architecture is that all life responds well to design that is energetically harmonious with nature. The Bio-Architecture approach embraces the eco-friendly practices of sustainable construction and the use of natural materials, as well as the energy conservation by mimicking the natural life. Since antiquity man has been fascinated and awed by the beauty of the natural world for example, in the regular patterns of crystals, living creatures (simple animals, plants, and flowers) or their parts, or even the human form. Architects in particular have found inspiration in natural forms, Structures in nature represent some of the most elegant and sophisticated forms, demonstrating complicated design and engineering principles. Digital techniques have advanced with a wide range in recent years, offering an exciting opportunity to represent, analyze, create, fabricate, and simulate architectural forms inspired by nature which benefit the practice of architecture, by enabling new capabilities to integrate considerations of aesthetics, materials, structure, and environmental controls. ([Aizenberg J.](#) and [Dorsey J.](#), 2011)

### **1.1. Problem Definition:**

At the beginning of 2007, 6.6 billion people are living on earth and with this huge growth of the world's population, the rapid development in technology and economy creates an enormous impact on the environment and as a consequence built environment has replaced the former natural environment that has been managed to be transformed to fit human needs. Therefore the design of the built environment is becoming more important with the qualities of life which could be found in nature in order to be introduced into the artificial, cultural, or social, environment to maintain quality of life and biodiversity. In studying the environment necessary to support life, it may be possible to redefine the function of architecture as a discipline which enables people to build spaces which have a physically positive effect on living things.

It has been commonly noted that the main perception of nature influenced forms is basically aesthetic while little concern is given to the importance of inspiring from nature in the construction and structural performance of buildings as well as in the natural ecological architectural solutions.

## **1.2. Research Question:**

Can the biological characteristics of natural life and the built environment offer new solutions for more appropriate, bio-eco architectural designs?

What are the potentials of Bio-inspired architecture that can contribute to better quality of life?

## **1.3. Hypothesis:**

Inspiring architecture from nature will help to find ways for safe guarding the biodiversity of the environment from being destroyed; thus, biomimetics in architecture will help develop a culture of active environmental design which will not only reduce the negative environmental impacts but will also creates a positive environmental, social and economic solutions.

Bio-inspired regenerative architecture can develop the design of mutual relation between the built and natural environment.

## **1.4. The scope of this paper:**

This paper focuses on Exploring different approaches of Bio-Eco inspired architectural showing the potentials that can be offered by these natural inspired innovative solutions for more appropriate truly sustainable environment.

## **1.5. Importance of this paper:**

Architecture has to adapt to environmental changes, if pollution continues, architecture will have to provide shelter from a potentially hazardous future environment. The investigation of biology and natural processes makes architects aware of the ongoing processes and the influence they can achieve as biological research in biomechanics and functional morphology which are the basis for the further development of innovative materials and structure.

## **1.6. Aims and Objective**

This paper aims to draw attention to the importance of Bio-inspired building design in order to preserves the biodiversity in the natural environment as well as contributes towards creative inspiration design solution.

## **1.7. Objectives:**

- To explore the significant relationship between biology and architecture, Thereby to examine that new bio-inspired architectural design, structural types and materials can lead to a change in the culture of ecological architectural design and forms.

- It is hoped, to show that the successful collaboration between the architect and biologist serve to produce high quality and innovation ecological design in contemporary architecture.
- To motivate designers, architects and engineers towards restoring the ecosystem and improving the social systems that exist in the surrounding as well as increasing professional awareness toward the potentials of applying the bio-ecological feature in their innovative designs.

## 2. Exploring different thinking of Bio-Eco Architectural Design

There has been different efforts and experiment along different level of intervention which has been done and applied in the past with a very simple approaches and others that are currently developing to face the rapid development of advanced technologies to apply the concept of bio-inspired regenerative architectural design and construction for achieving the contemporary concept of eco-sustainable environment which will not only reduce the negative environmental impacts but will also creates a positive impacts.

### 2.1. Algae Farm and Bio-Hydrogen Airship, Emergency Housing, Scientific Laboratories, Freight, Shanghai, South China Sea, Vincent Callebaut Architectures



Figure (1): floating Algae farm inspired from the shape of seaweeds found in ocean that recycle the  $CO_2$  for the bio-hydrogen flying airship Source: <http://vincent.callebaut.org>

bio-mimicry which is hard to be made at present. But it maybe will come true in the future as this concept depends on the technologies that are being developed; it draws its inspiration from:

- The beauty and the shape of the nature
- The qualities of its materials
- Natural phenomena
- Energy found in nature

(a) The Beauty and The Shape Of The Nature:

Inspiring the form from the shape of seaweeds found in ocean makes the building responds to the natural environment where it belongs, thus, preserving the ecosystem and biodiversity of the site. (*Klanten R. and Feireiss L.,2011*)

(b) The Qualities of Its Materials:

This flying castle draws its inspiration from the bio-mimicry technologies:

-It is built in lighter & more resistant composite materials (fiberglass & carbon fiber) in order to reduce the weight of its structure at the maximum, thus, reducing the emission of co2.

-It also uses Nano-structured glass inspired from the lotus leave that does not get wet and is self cleaning.

-The vessel is made of (intelligent layers) which avoid the accumulation of ice or snow and (self-separable ceramics) offering a bigger resistance to split and fill the cracks. This bionic coating draws also its inspiration from shark skin that enables without being toxic to avoid the adhesion of bacteria whereas the four wings present irregularities of surface, as the finely beaded whale fins do, in order to reduce the turbulences. (*Klanten R. and Feireiss L.,2011*)

(c) Natural Phenomena:

As biotechnological prototype, it aims at being the symbiosis of ecosystems, it deals with reinventing the industrial, town-planning and architectural processes to produce clean solutions and create an industry where everything is recycled and reused, either back to the ground under the shape of not toxic (organic nutrients) or back to the ground under the shape of (technical nutrients) able to be indefinitely recycled using the concept of cradle to cradle.

-A farm with seaweeds is a real miniature biochemical power station that is capable of absorbing co2 as main nutrient by photosynthesis and producing hydrogen in bioreactors. This natural process, nourishing itself with human waste enable to recycle under the effect of the sun, in seaweeds or sea water baths, up to 80% of carbonic gas NOx which has a harmful impact on the green house effect.

-This floating purifying station is an observatory of the sea funa and flora that fight for the protection of ecosystems and for the revitalization of beds of corals

and of endangered species. It is a true cleaner of seas and oceans by skimming and damaging as main nutrient the floating waste banks of energy-consuming civilization. (*Klanten R. and Feireiss L.,2011*)

(d) Energy Found In Nature:

The buildings are 100% self-sufficient in energy and zero carbon emission. All sources of renewable energies have been integrated in the project. (Solar- wind-water energy- biogas)

The inhabited vertical airship sets in the heart of a floating farm of seaweeds that reload it directly with bio-hydrogen. The floating farm is a true organic purifying station composed of 4 carbon wells in which the green seaweeds recycle the carbonated waste brought by ships as well as producing a great amount of bio-fuel. The farm organizes on a radiant plan, the seaweed bioreactors exposed to the zenith sun under the lenticular accelerators for a better photochemical output. At the surface, arches are covered by thermal and photovoltaic solar shields whereas under the water they are set with 32 hydro-turbines transforming the tidal energy of the sea streams into electricity. The inflatable bubbles are glue-backed with flexible photovoltaic cells as well as the four wings of the vessel are each of them inlayed with turbi-propellers with recuperation of energy. The inhabited spaces integrate by steps vegetable gardens photo-purifying the used waters, the biomasses damaging the organic waters and located fuel cells. (*Klanten R. and Feireiss L.,2011*)

(e) Structural and Function:

Forming a big flower ready to open, the spaces divide in cross under the shape of petals that welcome respectively the main sectors of activities: housing, offices, scientific laboratories and entertainment. These 4 inhabited spaces are included between 4 great bubbles inflated with bio-hydrogen. These bubbles are made with a rigid hull in light alloy shaped with twisted longitudinal beams linked together by wide sinusoidal rings. Continuing the 4 wings of the pneumatic tower, 4 great arches structure this circular platform and distribute vertically all the levels of the central ring inhabited by the scientists. (*Klanten R. and Feireiss L.,2011*)

## **2.2. Coral Reef – Matrix for the Construction of 1000 Passive Houses, in Haiti / by V. Callebaut Architecture**

The project had drawn its inspiration from:

- The beauty and the shape of the nature
- Natural phenomena
- Energy found in nature



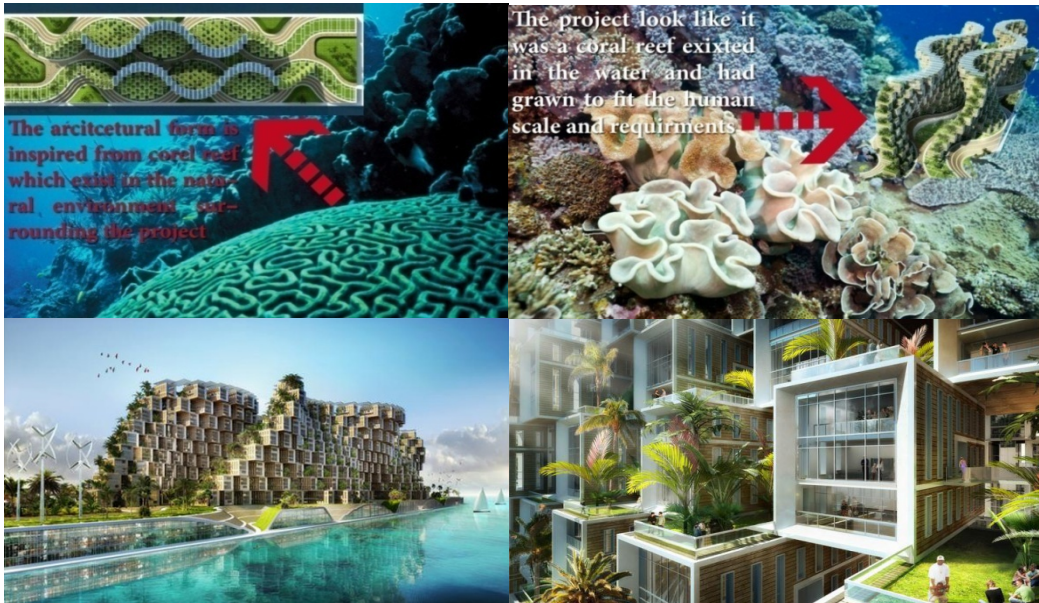


Figure (2): The architectural form is inspired from Coral reefs which exist in the place.

Source: <http://vincent.callebaut.org>

(a) The Beauty and The Shape Of The Nature:

Inspiring the form from Coral reefs with fluid and organic shapes, the overall project presents itself as a great living structure made of two waves for the housing of more than one thousand Haitian families. The two inhabited waves undulate along the water on an artificial pier built on seismic piles in the Caribbean Sea. Between the two inhabited waves is created a terraces and cascades of food gardens. Each roof of each module becomes an organic suspended garden enabling for each family to cultivate its own food as well as using their own wastage as compost. (<http://vincent.callebaut.org/page1-img-coral.html>)

(b) Natural Phenomena:

This canyon is a tropical ecosystem for the local fauna, flora and of the urban biodiversity, it is also the central axis of the communitarian life of this futuristic village and respectful of its environment. Between the waves of these ecological housing, the sinuous lines of the anti-seismic basement (absorbing the vibrations in case of earthquake) integrate the public functions of the social life. Aquicultural farms welcome pisciculture pools whereas the purification plant lagoons recycle the used waters before rejecting them in the sea.

(c) Energy found in nature:

The Coral Reef project plans a matrix to build an energy self-sufficient village. The project is eco-designed and integrates all the bioclimatic systems as well as the renewable energies. The sinusoidal pergolas on the roof attract the solar energy by photovoltaic panels and a park of spiral wind turbines is planted in the

great tropical garden that covers the logistical basis and turns it into electrical energy.

(d) Structural and Construction Process:

The visible sinuosity of this built landscape is structured by eight spine columns integrating all the vertical circulations linked together by two horizontal floors crossing through a straight line the whole village from end to end. The standardized and prefabricated module is built in order to re-house the refugees from humanitarian catastrophes. This basic module is simply made of two passive houses (with metallic structure and tropical wood facades) interlocked in duplex around a transversal horizontal circulation linking every unit.

### 2.3. The onion house, Kailua-Kona, Hawaii:

Organic Architecture has been described as the creation of structures in harmony with nature, their sites and their surroundings. This movement is aptly represented in the onion House.

*“This home takes advantage of the natural breezes that come from the ocean in the day and from the lavaladen mountains at night. It was built for the joy of living in the tropics.”*

— Ken Kellogg, architect

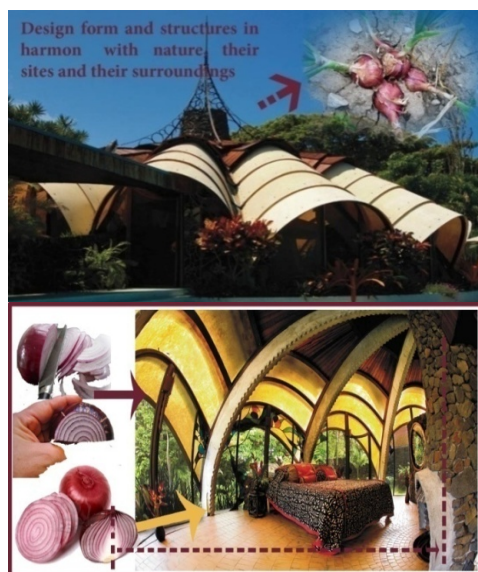
The project had drawn its inspiration from:

- The beauty and the shape of the nature
- Qualities of its materials

(a) The beauty and the shape of the nature. Started looking at the environment and began building with eco-inspired homes, the house is designed in tune with the curves of an onion, with a layered feel that mirrors the lucid skins of an onion. It is a beautiful demonstration of the possibilities when nature is a design icon.

(b) Qualities of its materials

Using of local materials composed of lava rock walls and intersecting concrete arches will reduce the use of materials. Light filters through the translucent, arched roof panels made of Alsynite (a type of fiberglass), casting colorful spectrums across the house. Stained glass and mosaic tile work was crafted by artist James Hubbell. (*Ozibel H.*, 2011)



Figure(3): The onion house is designed in tune with the curves of an onion

Source: <http://www.onionhousehawaii.com/whtArticle.html>





Figure (4): The city takes the form of the swirling of the sea, showing how to such  $CO_2$  and make it as building material; Source: <http://www.globalcoral.org/Ocean-Grown%20Homes.htm>

#### 2.4. Self-Assembling City from the Sea-Autopia Ampere (Eco-Island City)

**This Artificial Island by the German Architect Wolf Hilbertz** (the father of sea-creation) is a self-sustaining island city on Seamount Ampere, which is situated about halfway between the Madeira Islands and the tip of Portugal. If constructed, it will extend 50 ft. down to the bottom of the Atlantic in that spot.

The project had drawn its inspiration from:

- The beauty and the shape of the nature
- Natural phenomena
- Energy found in nature
- Materials, Structural and construction
- process found in nature
- Preserving the ecosystem and the biodiversity of the place

(a) The beauty and the shape of the nature

The city takes the form of the swirling of the sea where the logarithmic spirals were interpreted to mimic the natural force flows of cantilevered structure to its foundation, while minimizing the amount of materials.

(b) Natural phenomena:

Biomimicry proposes biological models to directly “suck”  $CO_2$  from the atmosphere like plants, or through water like mollusks when building their shells. **Inspired from the mineral accretion the technique that has built corals reefs in the caribbean and in the Mediterian Sea.** This allows to dream of making the carbon fixed as calcium carbonate the ultimate building material.

(c) Energy found in nature:

A huge limestone dam will surround the city and building components will be grown in the sea. Solar and wind generators will furnish power. A thermal energy conversion system will extract power from temperature differences among different ocean currents.

(d) Materials, Structural and construction process found in nature:

The visionary designer Hilbertz has found a way to use sunlight to turn the minerals in seawater into limestone as self sustaining construction materials for

underwater and dryland constructions. This represents the ultimate application of the "mineral accretion" building technology. Autopia Ampere will begin as a series of wire-mesh armatures anchored atop a sea mountain. Once in place, they will be connected to a supply of low-voltage direct current produced by solar panels. Over time, electrochemical reactions will draw minerals from the sea to the armatures, creating walls of calcium carbonate, which is also called limestone. By removing carbon-containing compounds from the oceans, the mineral accretion process would help reducing the buildup of CO<sub>2</sub> as a greenhouse gas.

(e) Preserving the ecosystem and the biodiversity of the place:

Coral reefs are one of the most complex marine ecosystems, important to sea life and protective of shorelines from erosion that's why the limestone structures in the sea will facilitate the growth of Coral reefs and provide habitat for fish and other coral reef species. This method is sustainable, environmentally safe, and economically and biologically feasible.

## 2.5. Ice Hotel In Sweden



Figure (5): The Ice Hotel Sweden

Source: [Kowalewski B.](#), [Kindersley D.](#), 2009

The Ice Hotel Sweden, first constructed in the late 1980's, is built and re-built each winter in Jukkasjarvi, located about 120 miles north of the Arctic Circle. Each year, the ice hotel has a different design, usually spreading over a space of about 53,700 feet. The Sweden Ice Hotel is open for business beginning in December (depending on the weather) and ending in March.

The project had drawn its inspiration from:

- The beauty and the shape of the nature
- Qualities of its Materials
- Preserving the ecosystem and the biodiversity of the place

(a) The beauty and the shape of the nature

The project form is inspired from the houses of polar animals where they belong, this help in preserving the ecosystem and the biodiversity of the place.

(b) Qualities of its Materials

It is built completely out from blocks of ice drawn from a nearby river.

It uses more than 4,000 tons of ice to create the igloo-like structure, and usually features roughly 60 guest rooms. Not only is the entire Sweden Ice Hotel structure made totally of ice, but all of the furniture and most of the décor found within is also made from ice. ([Kowalewski](#) B., Kindersley D., 2009)

## 2.6. Snail Home (The Nautilus House)

The [Nautilus House](#) is a gigantic shell-shaped design located in Mexico City.



Figure (6): The Nautilus House: Live In A Giant Designer Snail Shell, 2006 Source: *Senosiain j.*, 2008

The project had drawn its inspiration from:

- The beauty and the shape of the nature
- Qualities of its materials
- Preserving the ecosystem and the biodiversity of the place

(a) The beauty and the shape of the nature

It is a snail-like structure where the logarithmic spirals were interpreted to mimic the natural force flows of cantilevered structure to its foundation, while minimizing the amount of material used, thus, reducing co2 emission on the environment.

(b) Preserving the ecosystem and the biodiversity of the place

The house look like a small snail which belongs to the garden and then grown to fit the scale of a human shelter.

(c) Qualities of its materials

Senosiain Arquitectos used ferrocement to construct the nautilus-like home.

Ferrocement is a composite material which is used in building or sculpture with cement, sand, water and wire or meshes material, due to its ability to be moulded into a wide range of complex forms, and is often called a thin shell in North America.

It is a maintenance-free structure and an earthquake resistant material that is very flexible when wet yet exceptionally strong when cured. (Senosiain j., 2008)

### **Conclusion:**

The possibilities of learning from nature are as endless as nature is diverse. Architects, engineers and designers must take advantage of that wealth of knowledge to aid in more ecological architectural design solutions. Those regenerative solutions cannot be achieved without working with biologists, natural historians and others which will offer more accessible information on the natural world. Learning from nature for design inspiration will shape the designs of the 21st century for more healthy, productive and innovative environments where all buildings have to be zero environmental impact and maximum comfort. Bio-eco regenerative architectural designs are not looking only to nature for clues on how to capture energy from the sun, how to heat and cool buildings, manufacture materials, and even design communities as well as how to reduce the harmful impacts of buildings on the environment but also how to create living buildings that should have positive impact on the environment as living creatures do in nature. In the future world will be designed to function like living organisms, specifically adapted to place and able to draw all of their requirements for energy and water from the surrounding, while the main role of the architect will be how to design an “Ecomorphic buildings” buildings that mimic natural systems and have the capacity to reconnect people to nature.

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