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# Biomimetic strategies for climate change mitigation in the built environment

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**Abstract**

Out of the numerous challenges facing mankind globally, the impact of climate change poses more threat. These impacts include sea-level rise, more frequent floods from heavy rainfall and notably among others, intense droughts. Despite the United Nations anchored events and conferences geared towards tackling climate change, little success has been recorded till date. Biomimicry, a novel science and method that studies nature's models and then emulates their forms, processes, and strategies offer a sustainable approach to this menace of climate change. It also has the potential to offer efficient alternatives to the human activities that contribute to the depletion and pollution of the environment. Hence, the objective of this paper is to evaluate and present the potential of biomimicry in for climate change mitigation in the built environment. An extant literature review was conducted on biomimicry and its roles in tackling climate change through mitigation and adaptation. The result explores various Biomimetic innovations and applications with their potential to sustainably mitigate the menace of climate change if adopted. This study is expected to refocus human efforts towards biomimicry where it is believed that nature, during its 3.8 billion years of existence has evolved with highly efficient processes and systems, with the potential to produce solutions to the environmental challenges facing mankind, especially climate change.


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*Keywords*: Biomimicry; built environment; climate change; greenhouse gas; nature.

## 1. Introduction

Among the global problems, climate change is often cited as the most serious threat facing humanity as the impacts now affect all countries and regions around the world, albeit in different and uncertain

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ways [1]. In the progress towards rapid urbanisation, statistics has shown that human activities contribute heavily towards environmental degradation and pollution. The importance of plants and equipment in the delivery of infrastructural project objectives seems to be increasing on a daily basis [2], all in a bid to match and sustain the growth. However, the fuel and energy used to power these plants and the resulting exhausts/emissions negatively impact the environment. Today, we primarily use fossil fuels to heat and power our homes as it is convenient using oil, coal and natural gas for meeting our energy needs [3]. These are done without a conscious consideration for the environment, the resultant effect been the rapid increase in the atmospheric concentration of pollutants.

Atmospheric concentrations of greenhouse gases (GHGs) are already well above pre-industrial levels and are projected to continue rising rapidly [4]. The increase in GHGs within the atmosphere is changing the manner in which radiation is transmitted within the atmosphere resulting in global warming [5]. Carbon dioxide ($CO_2$), among several others, is the primary GHG that has contributed to recent climate change and known to be directly emitted by humans [6]. It has been discovered that buildings are major emitters of other non-$CO_2$ GHG emissions such as halocarbons, chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) as a result of their use for cooling, refrigeration, fire suppression, and in the case of halocarbons, insulation materials [7]. These other GHGs are known causal agents of respiratory health problems, headaches, dizziness, irritation of the eyes, nose and throat and other illness. Other impacts also include sea-level rise, changes in storm paths and frequency, more frequent floods from heavy rainfall and among others, intense droughts leading to food shortages etc. [7] [8].

Policies and actions to combat GHG emissions must expand rapidly as the impacts of climate change bites and increases [9]. It is, however, noteworthy that, during nature's years of evolution, it has evolved highly efficient systems and processes, which can propel solutions to many of the challenges we now grapple with today [10]. By responding to its need and finding solutions that work, nature evolves [11] and sustains itself over the long haul. For 3.8 billion years, 10-30 million species have learned to do everything humans want to do, without guzzling fossil fuels, polluting the planet, or mortgaging the common future of generations to come [12]. $CO_2$ removal from the atmosphere by the photosynthesis of plants and the absorption of $CO_2$ for pH level reduction by the oceans [3] are few of the highly successful strategies found in nature. This discovery has therefore birthed an era whereby humans consult nature, studying their forms, processes, systems and strategies to solve problems. Biomimicry, the term describing this practice, will be construed in this study. In light of the conclusions reached, a long-term biomimetic solution is proposed thereby utilising the synergy of strategies found in nature with respect to tackling climate change.

## 2. The United Nations Framework Convention on Climate Change (UNFCCC)

At the Rio Earth Summit in 1992, countries joined in an international treaty, the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC is a framework for international cooperation to combat climate change by limiting average global temperature increases and the resulting climate change, and adapting to the inevitable impacts [13].

Climate change is a large-scale global and long-term issue full of uncertainties [14]. Regardless of the stance held by individuals, societies or governments on the sorts or magnitude of change occurring, an important consideration is the changing nature of change itself: its pace is quickening; its intensity increasing; its symptoms are more obvious; the consequences and severity of change are more evident; and it is fomenting additional and more ferocious change [15]. The primary objective of the UNFCCC, as stated in Article 2 is mitigation leading to ''… stabilisation of GHG concentrations in the atmosphere ….'', but within a time frame that allows ''…ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable

manner'' [16] [17]. Although, adaptation and abatement/mitigation of GHGs emissions are both set out in the UNFCCC as responses to anthropogenic climate change, a dichotomy between the two as policy approaches has emerged as one of the most striking features of the discussion on how to respond [18].

## 3. Adaptation and mitigation responses to climate change

The duo of mitigation and adaptation has been recognised as being responses to the issue of climate change, as most of the scientific analysis and literature to date has tended to treat them as separate domains, with very little overlap [4] [17]. While mitigation focuses on the source of climate change, adaptation addresses its consequences [18]. The relationship between them is such that, in theory, the more mitigation that takes place, the less adaptation will be needed, and vice versa [4]. The visible effect of mitigation is not usually immediate, just as the impact of climate change seen now is as a result of long years of accumulated atmospheric concentrations of GHGs and other causal agents. Mitigation is, however, the best path and response to climate change as it assures of a permanent and long-term remedy since adaptation addresses the immediate consequences of climate change. Thus, mitigation was the policy response of choice in the early stages of the UNFCCC because adaptation was considered only as the secondary response [18]. It is therefore recognised that, whereas mitigation comes down to following regulations and making conscious changes in production, transport, and other service industries, adaptation will not be an optional action [18]. The synergies between adaptation and mitigation responses to climate change should be highly effective and efficient considering the extent of the impacts till date. Owing to sustainable practices found in nature, the adoption of biomimicry thinking is more than needed now, in other to proffer mitigation measures to climate change.

## 4. Biomimicry overview

Originating from the combination of Greek words; *bios* (life) and *mīmēsis* (imitation), biomimicry literally means life imitation or the imitation of life [19] [20] [21] [22] [23] [24]. Biomimicry is a novel field popularised by an American biologist, Janine Benyus in her book titled Biomimicry: Innovation Inspired by Nature. Biomimicry *(bi•o•mim•ic•ry)* studies nature's models and then emulates their forms, process, systems and strategies to solve human problems in a sustainable manner. Multiple terms such as bionics, biomimetics, biognosis and bio-inspired design are also used to describe this practice of learning from nature and emulating its systems [23] [25] [26]. Biomimicry is currently gaining overwhelming significance as a global movement in design for environmentally conscious sustainable development that often stimulates creative innovations and solutions [23] [26] [27] [28]. Al Amin and Taleb [29] believes that biomimicry as an approach has the potential to solve human challenges due to the fact that other organisms in nature face, or have faced many of such challenges we face as humans and were able to overcome them. No doubt biomimicry is the best path to a better and sustainable future for mankind as it hopes to solve the problems created by the uncontrolled global growth of industrialisation and the exploitation of natural resources [30]. A wide range of multinational companies and organisations now embrace biomimicry in their quest for sustainability, efficiency and effectiveness.

## 5. Biomimicry mitigative response to climate change in the built environment

Biomimicry has the potential to tackle climate change by mitigating GHG emissions which remain the primary causal agent. Biomimicry can mitigate against the effects of climate change through the following ways: application of biomimicry for energy effectiveness and energy efficiency; biomimetic energy generation; and biomimetic sequestration and storage of carbon [31]. Nature has been found to be

a master in dealing with chaos, complexity, and unpredictability. Learning from the processes, systems, and strategies at work in nature can be adopted, providing both mitigative and adaptive responses. Successful research and development from nature's over 3.8billion years of evolution has resulted in finding what works with the results found to be sustainable, efficient, functional and aesthetically pleasing as well. For example, before the industrial boom, the atmospheric concentration of $CO_2$ remained steady as the continuous exchange of $CO_2$ between the atmosphere, oceans, and land keeps a balance. Professional innovators, designers, and researchers are now heading outside to see how species have managed to survive all these years [32] after been humbled and inspired by the flora, fauna or an entire ecosystem's modus operandi. It is, therefore, imperative for us to humbly look unto nature as model, mentor and measure in other to find numerous and sustainable solutions to the challenges facing mankind, one of which is climate change amongst many others.

### *5.1. Biomimicry for energy effectiveness and energy efficiency*

It has been discovered that buildings are high energy consumers and major emitters of other non-CO2 GHG emissions such as halocarbons; chlorofluorocarbons (CFCs); and hydrochlorofluorocarbons (HCFCs) as a result of their use for cooling, refrigeration, fire suppression, and in the case of halocarbons, insulation materials [7]. In general, improving energy efficiency in human activities is an important part of addressing climate change, but is, however, an intermediate step [31].

Emulating the effectiveness of living organisms and systems in transforming materials and energy in a way that is less resource intensive has the potential of improving the energy efficiency of human beings. Living organisms offer innovative and sustainable methodologies and strategies on how humans can perform their activities without depending on fossil fuels. The impetus is that by being more energy efficient, less fossil fuel is burnt and therefore less GHGs are emitted into the atmosphere [9]. Nature uses 'free energy', as the majority of ecosystems exist through utilising contemporary sunlight (recently received from the sun) that has been converted by photosynthesis into biomass, wind-dispersed seed pods using air currents, or marine mammals exploiting water currents in migration [28]. The efficient method displayed by nature to harness and use the sun's energy is a prime example of energy efficiency and effectiveness [19] that should be adopted as mitigative measures for over-dependence on fossil and other types of fuels that generate and contribute to the level of $CO_2$ in the atmosphere. This has been the primary energy source of living organisms, powering their activities through their 3.8billion years of evolution with zero CO2 and other GHGs emitted.

For instance, a major example of biomimetic buildings is the iconic Harare's Eastgate Centre in Zimbabwe, which is the country's largest office and shopping complex. In order to accomplish the goal for a sustainable building with lower levels of energy usage [33], the lead architect, Mick Pearce studied the structure of the mounds of southern Africa termites (Macrotermes michaelseni). He reasoned that the architectural principles of the termite mound, honed to sleek efficiency by the principles of induced flow and the use of thermal capacity to regulate temperature and the relentless refining of natural selection, could inspire buildings that perform equally well which by all measures had his vision succeeded brilliantly [9] [33] [34]. The Eastgate building was designed to have a relatively thermally stable interior environment that uses minimal mechanical cooling and therefore produces fewer GHG emissions [9]. The building is ventilated, cooled and heated entirely by natural means, using no conventional air-conditioning or heating systems and thus consuming 90% less energy than a conventional building of that size [33].

### *5.2. Biomimetic energy generation*

A major challenge facing mankind, which is energy generation has been successfully and sustainably addressed by natural organisms. Looking to the world of nature, it will be interesting to note that natural organisms optimize energy use mainly sourced from renewable avenues, predominantly sunlight (operating solar economy as against fossil fuel economy). Many plants are able to sense the direction of the sun and therefore grow or move towards/away from it, enabling greater photosynthesis efficiency or other advantages [27] [28]. The Institute for the Future [35] informed that, leveraging the actual natural/biological systems behind photosynthesis (the process that plants use to convert rays from the sun into chemical energy), is now leading to the development of energy conversion systems also referred to as artificial photosynthesis. Several biomimetic technologies and systems developed aim to replace the use of fossil fuels as the primary energy source that human use in an effort to mitigate GHG emissions [9] [31] [36].

Drawing inspiration from the ocean/marine life (sea kelp and tuna tails in water), bioWAVE and bioSTREAM technologies are developed by an Australian company, BioPower Systems [9] [36]. BioWAVE is mounted on the sea floor, with a pivot near the bottom coupled with an array of buoyant float (blades) which interacts with the rising and falling of the sea surface (potential energy) and the sub-surface back-and-forth water movement (kinetic energy). As a result, the pivoting structure sways back-and-forth in tune with the waves, and the energy contained in this motion is converted to electricity by an onboard self-contained power conversion module called O-Drive. The O-Drive contains a hydraulic system that converts the mechanical energy from this motion into fluid pressure, which is used to spin a generator. Power is then transferred to the shore via a subsea cable resulting in the delivery of efficient clean energy from the ocean [37]. It is noteworthy that this technology is out of view, harmonious with the marine environment and eco-friendly.

### *5.3. Biomimetic sequestration and storage of carbon*

Although the production of carbon dioxide is a necessary result of burning fossil fuels, there exist possibilities of either capturing or storing it in the event of their release into the atmosphere [38]. The emulation of the processes and functions of organisms in nature that are able to store, sequester or recycle $CO_2$ have heralded the development of novel technologies that can be applied to industrial processes, the built and the human environment at large [9]. These are perceived to be safe technologies and systems with the potential to significantly mitigate the effects of climate change.

Several of the examples of biomimetic approach to carbon sequestration or storage discussed below reveal that novel innovations are birthed and useful products made, such as plastics and potential new building materials, without toxic by-products and the use of high amounts of energy [31]. For instance, the Rocky Mountain Institute is working on developing an alternative material to concrete which emulates the abalones' ability to grow a crack resistant shell that is harder than any manmade ceramic, through a process of biomineralisation - a carbon-storing process [36]. The working concept of trees and their functionality with respect to carbon sequestration and storage is one of the approaches to biomimicry which is beneficial to the earth and its inhabitants and will aid in the effectiveness and efficient generation and use of energy. Another interesting examples biomimicry offered are the Treepods designed by Influx Studio with the project aiming to create clean air by creating a system that catches $CO_2$. Treepods design is culled from the emulation of the Dragon tree because of its large canopy that provides maximum shading which also allows the structure to support solar panels used to power the air cleaning system [39]. Also, Novomer, a company formed out of a research done at Cornell University, is developing biodegradable plastics based on the carbon sequestration process in living organisms by turning carbon dioxide into carbon-based polymers [36].

It should be noted that biomimetic sequestration and carbon storage does not have the ability to address the challenge of excessive dependency and burning of fossil fuels. It does not also put into

consideration the high consumption of natural resources, significant waste generation and depletion of oil reserves. Rather, this approach is an interim step in the development of a more sustainable human society and economy, creating ample time to develop novel ideas and technologies that do not pollute less, but instead does not pollute at all [9]. Since nature has been able to successfully tackle most of the challenges facing humanity, it is important to embrace the novelty exhibited by nature in order for us to mitigate the menace of climate change. Drawing insight from the strategies exhibited by natural organisms, especially bio-mineralisation and their ability to use CO2 as a resource, concrete and cement materials with less environmental impacts have been developed. Examples of these are Blue Planet's bagged concrete, and TecEco's Eco-Cement, both offering sustainable carbon neutral alternatives to the construction material known to possess the highest CO2 footprint globally.

## 6. Conclusion and recommendations

With the rising population of mankind as evident in most countries around the world, coupled with rapid urbanisation, the negative environmental impacts of human activities are now evident, especially the issue of climate change which has received global attention. Mitigation and adaptation are the two widely recognised concepts with the potent panacea to the global challenge of climate change. While mitigation aim at both decreasing the energy consumption of buildings and limiting GHGs emissions, adaptation on its part refer to the mitigation of the consequences of natural hazards taking root in prevention and protection concepts [40]. The basics of biomimicry is that during its 3.8 billion years of research and development, nature has evolved highly efficient systems and processes, which can produce solutions to many of the waste, resource efficiency and other environmental problems that human cope with today [41]. Whereas, man has been after utilising natural resources for his benefits and welfare which has been accompanied by an imbalance in nature, the introduction of various pollutants into the atmospheric sphere and damaging of the environment [42]. It is believed that an holistic application of the triadic views of biomimicry (nature as mentor, model and measure) will culminate into the innovation and development of energy generation technologies burning less or zero fossil fuels. Rao [39] also affirmed that under this new order of sustainability, buildings, outdoor art and other manmade structures would function like trees, meadows, flora and fauna, capturing, cleaning and storing rainwater; converting sunlight to energy and carbon dioxide to oxygen; protecting soil from erosion; disseminating seedlings; and eliminating waste. This study shows that the coherence between the concepts of adaptation and mitigation is crucial [40] and the potential of biomimicry to offer solutions in both dimensions in a sustainable manner [9] [31] is eminent.

It is imperative to find ways of cushioning the effect of the resultant climate change through mitigation as one of the strategies put forward by UNFCCC and other researchers. This should, therefore, involve finding methods to replace the use of fossil fuels, reduction in carbon footprint, discouraging consumption of natural resources and subsequently minimising the generation of waste amongst others. Biomimicry has presented a mitigative path to tackling the menace of climate change in a sustainable way. Biomimetic examples presented in this study has shown its potential in developing technologies that addresses the excessive release of GHGs into the atmosphere. However, significant time, funding and collaboration between biologists, designers and innovators need to be adopted and encouraged in order to develop more of such technologies. This study has shown the ability of biomimicry to intercept rainfall thereby reducing the risk of flooding, limit overheating, sequester carbon to offset CO2 emissions and overall, improve human wellbeing and the environment. It is also important to note that biomimicry will protect and support ecosystem services which are known to have always aided good air quality for the human environment through their carbon sequestration and storage capabilities.

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