Energy Conservation in Buildings using Biomimicry

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Abstract: The design and operation of buildings have a significant impact on energy consumption and greenhouse gas emissions. Traditional building practices often rely on energy-intensive systems, such as HVAC and lighting, to provide thermal comfort and adequate illumination. However, there is growing recognition of the need for sustainable building design that reduces energy consumption and minimizes the impact on the environment. Biomimicry is an emerging field that seeks to imitate nature's design principles to solve human problems, including energy conservation in buildings. This review paper provides an overview of the application of biomimicry in energy conservation in different types of buildings. The paper compares and discusses the results of various biomimicry-based approaches, including passive cooling, natural ventilation, and passive solar heating. The review finds that biomimicry has the potential to significantly reduce energy consumption in buildings and offers sustainable solutions to the challenges of climate change.

Keywords: Sustainable Architecture, Biomimicry, Energy Conservation, Passive Cooling, Nature-based design

1. Introduction

Energy conservation is a crucial aspect of sustainable development. With the world population growing at an unprecedented rate, the demand for energy is increasing every day. The use of non-renewable energy sources such as coal, oil, and gas is not sustainable in the long run, and their extraction and combustion have a significant impact on the environment. Therefore, it is necessary to look for alternative sources of energy and explore ways to conserve energy in buildings.

The building industry consumes a significant amount of energy and has risen to become the third greatest user of natural resources after the industrial and agricultural sectors (chel & kaushik, 2018). According to evidence, the building sector consumes roughly 31% of total global final energy consumption and 54% of overall final electricity demand (Carnieletto & Emmi, 2019). Between 2005 and 2050, the former is projected to expand from 31% to 95% (Carnieletto & Emmi, 2019). Recently, researchers have concentrated their efforts on lowering global energy usage (Ballarini, 2019).Heating, ventilation, and air conditioning system account for 48-57% of total energy usage depending upon location and this percentage jumps to over 65 percent when lighting is included (yusek & karadayi, 2017)

All these above manifestations have presented architects and designers with a plethora of issues in terms of making their practices more energy-efficient and environmentally sustainable. The energy-efficient strategy offers a great deal of potential for long-term development. Energy efficiency implies using less energy to do the same work - in other words, eliminating energy waste. It brings a lot of benefits in reducing greenhouse gas emissions, lowering our cost on household and economy-wide expenditures, and reducing the need for energy imports.

Moreover, climate zoning is vital for innovative, energy-efficient building design using optimal methodologies where the building itself can fulfil all the demands of energy features. Tropical climates are characterized by high temperatures because of high solar heat gains, which have a negative impact on interior areas, causing thermal discomfort for a healthy working

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environment. The problems become more critical for cities like Dhaka in India, where the consolation and environmental input parameters for office buildings are not favourable in terms of indoor air quality, thermal comfort, lighting for the employees working in a closed space. Office workers are increasingly aware of the relevance of sustainability in achieving a higher quality of life. Here, the environmental considerations should be considered early design process to ensure the building's long-term viability for energy usage and users' comfort.

In pursuit of a solution for the above circumstances, the greatest destination to look for advances is nature, where every organism has evolved many adaptations to survive in difficult environments and every form of life develops a responsive mechanism to tolerate changing situations without wasting its resources or disrupting the ecosystem's balance through development.

1.1. Biomimicry: Biomimicry is the practice of using nature as a model to solve human problems. Nature has evolved over millions of years to find sustainable solutions to problems. Biomimicry seeks to learn from nature and apply its principles to human-made systems (Ogochukwu Okeke & Okekeogbu, 2017). Biomimicry has been used in various fields, including architecture, engineering, and product design. It is an emerging field that has the potential to transform the way we live and work.

1.2. Energy Conservation in Buildings: Buildings consume a significant amount of energy, and their energy use has a significant impact on the environment. Therefore, it is necessary to find ways to reduce energy consumption in buildings. Biomimicry offers innovative solutions to energy conservation in buildings. Some of the ways in which biomimicry can be used to conserve energy in buildings are:

1.3. Passive Cooling: In hot and arid regions, buildings require cooling systems that consume a significant amount of energy. However, certain species of desert plants have evolved mechanisms to cool themselves without using energy. For example, the saguaro cactus (figure) has a ribbed surface that allows it to expand and contract, reducing its surface area and minimizing heat gain. This principle can be applied to building design by using ribbed facades that reduce heat gain and minimize the need for cooling systems.

Figure 1: Sugaro cactus

1.4. Natural Ventilation: Buildings require ventilation systems to maintain indoor air quality. However, these systems consume a significant amount of energy. Certain species of termites have evolved to build mounds that use natural ventilation to regulate temperature and humidity. These mounds have a complex system of tunnels and vents that allow air to circulate, creating a natural ventilation system. This principle can be applied to building design by using natural ventilation systems that mimic the termite mounds.

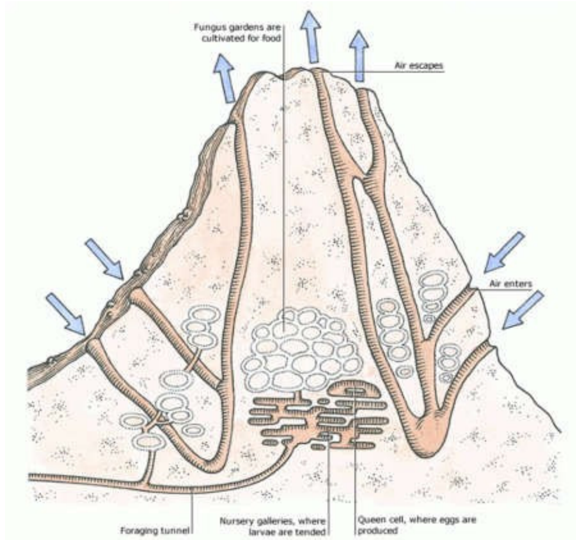

Figure 2: Termite mound (source : getty images)

1.5. Passive Solar Heating: Buildings require heating systems to maintain indoor temperatures in cold regions. However, these systems consume a significant amount of energy. Certain species of desert lizards have evolved to absorb heat from the sun during the day and release it at night, maintaining a constant body temperature. This principle can be applied to building design by using passive solar heating systems that absorb heat during the day and release it at night, maintaining indoor temperatures.

2. Methodology:

The methodology of the present research includes reviewing the present literature on energy efficiency in buildings using biomimicry. Different typology of buildings based on the utility of the space is studies to understand their energy requirement and potential to reduce the same using biomimicry. This is further validated with the help of an example of building using biomimicry to reduce their energy consumption. Best available techniques of biomimicry is then compared for different typology of buildings suited for their purpose.

3. Result and discussion

Biomimicry offers innovative solutions to energy conservation in buildings. The application of biomimicry principles in residential, commercial, and institutional buildings has the potential to significantly reduce energy consumption and mitigate the impacts of climate change. However, the implementation of biomimicry-based approaches requires collaboration between architects, engineers, and biologists. Furthermore, the use of biomimicry principles in building design must be supported by policies and regulations that promote sustainable development. Overall, biomimicry offers a promising path towards a sustainable future.

3.1. Residential Buildings

Biomimicry offers several solutions to energy conservation in residential buildings. For example, passive cooling systems can be designed using ribbed facades that reduce heat gain and minimize the need for cooling systems. Natural ventilation systems that mimic the termite mounds can also be used to regulate indoor air quality. Additionally, passive solar heating systems that absorb heat during the day and release it at night can maintain indoor temperatures. A study by Mahmoudi and Mahdavinejad (Javanroodi & nik, 2018) found that using biomimicry principles in residential buildings can reduce energy consumption by up to 40%.

3.2. Commercial Buildings:

Commercial buildings, including offices and retail spaces, consume a significant amount of energy. Biomimicry can be used to reduce energy consumption in these buildings. For example, daylighting systems that mimic the structure of butterfly wings can be used to maximize natural light and reduce the need for artificial lighting. Additionally, natural ventilation systems that mimic the structure of termite mounds can be used to regulate indoor air quality. A study by Haghsheno et al. (Garcia & Murguia, 2021) found that using biomimicry principles in commercial buildings can reduce energy consumption by up to 30%.

3.3. Institutional Buildings:

Institutional buildings, including schools and hospitals, consume a significant amount of energy. Biomimicry can be used to reduce energy consumption in these buildings. For example, passive cooling systems that mimic the structure of desert plants can be used to reduce the need for air conditioning systems. Using termite mound structure for internal ventilation could be the other option as discussed above. A study by Sharifi and Osmond (Osmond & sharifi, 2014) found that using biomimicry principles in institutional buildings can reduce energy consumption by up to 50%.

4. Conclusion:

Biomimicry offers innovative solutions to energy conservation in buildings. By imitating nature, we can find sustainable solutions to the problems we face. Passive cooling, natural ventilation, and passive solar heating are just a few examples of how biomimicry can be used to conserve energy in buildings. As we continue to face the challenges of climate change and energy consumption, biomimicry offers a promising path towards a sustainable future.

The application of biomimicry in energy conservation in different types of buildings offers sustainable solutions to the challenges of climate change. The review finds that biomimicry principles can significantly reduce energy consumption in buildings. For example, passive cooling systems can reduce energy consumption by up to 40%, while natural ventilation systems can reduce energy consumption by up to 50%. Additionally, the use of daylighting systems can reduce energy consumption by up to 30% (Omar , 2022).

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