Eco-Friendly Architecture: Mitigating Climate Change through Sustainable Design and Renewable Energy Integration

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Abstract

Architecture has been an integral part of society, and given the ongoing climate crisis, it is imperative that we adopt responsible architectural practices to help mitigate climate change. This paper will explore the significant benefits of eco-friendly architecture, such as using sustainable building materials. It will also show the efficient use of renewable energy sources such as solar, wind, and geothermal energy. Buildings such as the Green School in Bali, the Pixel building in Melbourne, and The Hemp House are examples of buildings that implement eco-friendliness and demonstrate how innovative architectural designs can mitigate climate change and offer a sustainable solution for the future while providing economic and social benefits.

Introduction

Architectural practices can positively impact climate change by using natural resources and becoming more eco-friendly. There are several significant benefits when the buildings become more eco-friendly and adapt to the environment. In this research paper, I will cover these benefits, such as using sustainable materials like wood, clay, rocks, or solar panels. I will also discuss how water can be conserved and managed and how biophilic materials can be used to create more diverse designs with the help of the environment.

Our world currently uses 40% of the world's greenhouse gas emissions. As the population increases, higher house demands result in a higher environmental impact. We can minimize the issue by balancing ecological technology and architecture using sustainable materials from the ecosystem. Our current method of building is indeed inferior and unsustainable. Many fossil fuels are used to make the skyscrapers that we see around us, emitting a lot of carbon emissions into the environment. On the other hand, using sustainable and renewable resources does not emit a lot of fossil fuel.

Green Materials and Design

The environment can metabolize water and energy within it. Like our bodies, it can recycle elements and also make waste. Through passive architectural systems, architectural designs may also benefit the environment. For example, implementing solar panels can reduce energy usage, make energy more efficient, and be used for shading. In the case of urban cities, ideas like green roofs will be constructive; not only will they make the architecture more distinct, but they will also reduce energy costs and the use of expensive drainage and cooling systems. If there are more of these green roofs, it will potentially reduce air pollution since more trees can be planted within urban cities. Building eco-friendly furniture using renewable resources from the environment can reduce the amount of new materials created. A few examples can include:

1. Green School

The Green School, designed and constructed in Bali, is a primary example of an eco-friendly architecture. The difference between the Green School and other conventional architectures is that the materials used are not fossil fuels or human-produced, which minimizes carbon footprint. The green school is designed with bamboo; bamboo is an excellent material for building architecture because it is very sturdy and flexible at the same time. Bamboo also regenerates on its own, reducing the use of fertilizers. Moreover, unlike fossil fuels, bamboo is not limited, so there is no need to worry about the material going extinct; it can be mass-produced quickly.

The Green School is also visually stunning. The arc design shows that even using environmentally friendly materials, the design is visually stunning. The arc has a ribcage design; like a ribcage, the bamboo acts like a thin but strong engagement. The bamboo can hold solid and sturdy arches and provide a grid shell shape. Since the gridshells are thin, the space provided by the arc will be significant, giving air circulation throughout the building.

2. Pixel Building

The Pixel building is the first office building with noncarbon emissions. It can generate all its power and water on site. It is over 840 square meters and was developed in 2005 by 505 studio architects. Illumination and natural ventilation are two pivotal requisites to minimize the building's energetic requirements so that the façade adapts to the building's needs at all times, which enhances its efficiency. The

Pixel façade includes intelligent window technology, which allows to open the windows automatically during cold nights to allow cool air to refresh the structure. Another essential feature of the Pixel building is that it collects rainwater and converts it to water we can use. The water is used in toilets and regurgitation systems throughout the building through filtration.

The most visible and characteristic feature is the colorful facade. This is made by using recycled color panels that maximize daylight, shade, views, and glare control. Since the panels can create shade and grey water treatments, this facade can provide greenery to every office floor. The facade wraps continuously around Pixel, creating a vibrant and unique identity. Pixel building features one of the most sophisticated water treatment and utilization systems. The building was built to be water-balanced and self-sustainable for water supply.

3. The Hemp House

The Hemp House is mainly constructed of "Hempcrete," a mixture of hemp fibers and lime. Hemp has been considered an excellent building material, replacing concrete and cement. Initially, the cement industry was responsible for about 8%. The search for alternative large-scale materials has been low. However, on a small scale, the alternative was found: Hemp. When mixed with lime, hemp created a low carbon content. This Hemp-lime material came to be known as "Hempcrete". Another ability of hempcrete is that it can pull carbon away from the atmosphere while growing. Hempcrete is more like an infill straw bale than a concrete. The Hemp House has a breathable wall system mixed with lime and on-site water. Hemp is a material that also naturally regulates a building's humidity and temperature, which can reduce energy condensation and energy consumption. The lime implemented on the wall gets progressively harder as time passes. The house's interior is also 100% eco-friendly and made from 100% post-consumer recycled paper. Recently, hemp's ability to capture carbon has increased twice as much. Researchers predict that at this rate, hemp will be able to capture carbon and sequester carbon enough to make carbon neutral.

4. Bioclimatic Dwelling in Tenerife

The Bioclimatic dwelling in Tenerife was constructed in 2003 using materials from the surroundings and zero energy cost in origin, including Tosca volcanic stone and riga recycled wood, glass, and concrete in gardening, waterproofing, and insulation. The architect does not need any heating or air conditioner due to its surrounding environment having benign weather conditions; thus, its climate emphasis on controlling air renewal, as well as the landscaping integration, makes it optimal for the house to harness wind power from its surroundings to use it for housing consumptions. Tosca stone walls made of stabilized double sheets are erected on the ground to host an inner air chamber that serves as a heat distributor of fresh air from the ground inside, where we utilize a venturi effect with radiation heating. Furthermore, the concrete slab, which is overlaid with topsoil and native planting, is irrigated with a drip system; the wet surface encourages evaporation, thus constantly regulating the temperature of the concrete mass from outside radiant response to the interior of the exposed mass to excess sunlight.

5. The Houl / Simon Winstanley Architects

The Houl is a long house that achieves a "zero carbon" rating through insulations, heat recovery ventilation, an air source heat pump, and a wind turbine. The pitch of the roof of the central living accommodation is that of the hilltop, with the roof of the rear accommodation meeting the main roof at a much lower angle to allow the morning sun to come into the area of the house through clerestory windows. It is a house built in a framework of steel and timber, supported by exterior walls and a roof with a cedar weatherboarding finish and pre-weathered grey standing seam zinc, respectively. Casements are with thermal breakage of wood, and all windows are triple-glazed.

6. Solar

Solar Panels help sunlight change into electricity through photovoltaic cells. When sunlight hits these photovoltaic cells, it generates electrical currents. These processes are very clean and renewable to the environment. The economic benefits, including solar panels in building architecture, reduce the payment needed for electricity. The Australian government also offers various incentives for solar installation and has advocated for it. Also, the government gave incentives in the UK, and technology costs dropped significantly. However, this made more energy-efficient homes more costly and of a higher value. But in turn, the social benefits of solar energy have allowed communities to generate their own electricity, reducing reliance on centralized power grids and providing greater energy independence and resilience, particularly in remote or rural areas. Solar farms have also benefitted the UK. Not only do Solar farms effectively provide energy, but they are also a great place for agriculture. Agrivoltaics is a term that refers to the sharing of solar panels and the domestication of crops in the same area. Agrivoltaics can show that solar panels do not take up space for agriculture and use the space effectively. For example, in Australia, solar technology provided a beneficial way for architects to incorporate it into their buildings.

7. Sundial Building Dezhou, China

The Sundial Building Dezhou in China is the world's largest office building that has implemented solar panels. The fan-like roof of the building has been designed to resemble the ancient "sundial." The "sundial" roof has solar panels on top of it, and the building houses exhibition centers, research facilities, meeting and convention spaces, and a hotel, all of which are powered by the hundreds of solar panels on the roof. Not only is the building itself very green, but there are many secrets to the architecture and structure of the building. One of them is the structure of the Sun dial, which is symbolic of the fact that the sun is one of the most renewable sources. Moreover, the building also features materials and construction methods for roof and wall insulation, which allows the building to save up to 30% more energy.

The “Solar Valley” 's main building is already what China calls “the biggest solar energy production base in the whole world.” Huang Ming hopes that this project will rival Silicon Valley in California. Ming also reveals his expectation that the “Solar Valley,” with the Sundial Building in the center, will help propel China’s renewable energy technology and installation development.

8. Apple Campus

Apple Campus was created by Foster + Partners. On the outside, it is just a simple-looking building, but it holds a plethora of professional work and creativity within it. It comprises a few core elements: physical cubic informal shared working areas, also known as ‘pods’ cooperative enclosed working stations that enable focusing on work and open, large, and shallow edge facades. Four thousand slabs make up The Ring’s floors, while the longest span is 48 feet. Called ‘void slabs’, these multifunctional building components create structure and exposed ceilings, house radiant heating and cooling systems, and offer air return. Moreover, becoming a campus town square, the restaurant occupies the whole NE Ring. People can mingle in the dining hall and on the outdoor terraces. The Fitness & Wellness Center is a building containing a retreat in the Apple Park scenery arrangement. Seen from the South, it looks like a two-storied lightweight construction: the extensive extended glazing gives the exercise and treatment rooms an impressive view of the parkland.

The Apple Campus was built in 2017, it consists 17 megawatts of solar on rooftops and is also supplemented by 4 megawatts of Bool energy fuel cell. The park is surrounded by trees, which are drought tolerant, and grass, making the environment very green. The building provides 800 45-foot tall round glass panels, and the whole building is 100% renewable energy. Moreover, the building won’t need any conditioner or heater for nine months in a year because the building conserves energy.

9. The White House

The White House installed three solar energy systems in 2002. The first system is placed on the roof, and there are 167 photovoltaic panels to maintain energy in the building. The second system is a solar thermal application that provides hot water on the ground. Lastly, the third system is used to heat hot tubs and showers and maintain the overflowing water in the outside pool.

10. Geothermal

Geothermal systems involve using some of the elements of the earth, such as the ground and water that is heated, to produce efficient systems for construction. These systems harness the constant temperatures beneath the surface of the earth, and as a result, can warm or cool spaces thereby reducing the use of conventional energy. This renewable energy method reduces the levels of greenhouse gases emitted into the atmosphere and the cost of energy in the long run as well. Geothermal systems' incorporation into the designs of buildings encourages sustainable technologies, thereby reducing any adverse effects on the environment and the consumption of fossil fuels. Hence, geothermal energy is the center of producing environmentally sustainable and power-efficient structures.

Furthermore, geothermal systems offer an ideal heating and cooling technique that uses favorable temperature fluctuation beneath the earth's surface. These different renewable energy technologies jointly help in lessening the emission of greenhouse gases, pointing toward energy independence and building designs' sustainability.

11. Gettysburg National Park and Military Museum

The geothermal systems in the Gettysburg National Museum contain 168 wells drilled to the average depth of 550 ft. The heat recovery chillers are equipped with 20 scroll compressors, which work in cooling circuits throughout the year and produce chilled and hot water at the same time. In summer, whenever the hot water return temperature goes on the high side of its set point the two way control valve provided at the condenser heat exchanger will open to the maximum extent and more heat is rejected into geothermal water. In winter, the two-way control valve at the evaporator heat exchanger opens. In contrast, in modulating to let the heat from the geothermal, the condenser hot water flow extracted from the condenser hot water storage tank through pump five and added the required amount of make-up water into the return chilled water flow to maintain a sufficient flow rate to the condenser hot water loop.

12. St. Patrick's Cathedral

Construction of St. Cathedral started in 1858 but did not open until 1879. After it opened, it brought over 5 million visitors. Before 2017, the cathedral's heat was provided by oil, but after 60 years, the church decided to replace its method and switch to a geothermal heating and cooling system. By reducing its carbon footprint, the cathedral is helping to make NYC a cleaner and more sustainable city. The cathedral is the largest building in Manhattan that uses geothermal heat pump technology. Not only is geothermal a more sustainable option, but it's also financially sound. The switch was "the most sustainable, cost-effective, long-term energy option for the cathedral," Monsignor Ritchie said. The cathedral estimates they've eliminated the cost of burning 218 barrels of oil per year, reducing its yearly expenditures and carbon dioxide emissions by 30%

13. Boston University's Center for computing and Data sciences

Boston University's new building, the Center for Computing and Data Sciences, has used most of its energy from underground and geothermal resources. The building's cooling and heating needs are mostly through energy underground. The building also provides highly efficient concentrate heat exchangers to maximize energy exchangers of ground source heat pumps. Thirty-one geothermal wells ensure no combustion is needed to operate the building. Moreover, the water of the building circulates approximately 1500 feet underground yearly. In winter, the temperature will be boosted to provide warm air, and in the summer, the temperature will be cooled to provide fresh air.

14. Wind Turbines

Wind turbines are crucial for managing the environment because they can produce energy without the need to release greenhouse gases that hinder the environment. Moreover, using wind energy through wind turbines will help to decrease dependence on nonrenewable sources like fossil fuels, which results in global warming. Also, wind energy is an energy product that is a constant source of power, so people do not have to worry about lacking energy. Wind turbines also do not require much land to be installed, and that area could also be used for other means, such as farming, thereby making environmental and economic profit.

15. House 2.0

House 2.0 is located in Amsterdam, Netherlands, with an area of 230 mm squared. It finished its construction in 2009. This second version of the House has pushed its boundaries further than the previous one. This house is energy-neutral and built according to cradle the cradle principle, reducing CO_2 by 100%. Moreover, the reduction of CO_2 is brought by bringing the house to a passive level using something called triple glazing, 100% liquid-tight joints and heat exchangers, and the integrated photovoltaic cells in the roof line and the windmill and PV cells work together to generate enough electricity within the house such as the electricity demands and the heating of water. Furthermore, the air supply comes from outside and is heated by a sole ground source heat exchanger, which are 2 meters underneath the ground.

Conclusion

In this research paper, I showed how green building designs present immense possibilities for reducing global warming by properly using sustainable materials, water, and advanced biophilic structures. Using materials such as wood, clays, rocks, and solar panels to facilitate the use of fossil fuels also reduces carbon footprint. The Green School in Bali, the Pixel Building in Melbourne, and the Hemp House are examples of the ideal combination of functionality and shining sustainability. Others include solar power, wind power, and geothermal power, which work together to achieve expansive energy efficiency and also help reduce the effects on the natural environment. The Sundial Building in China and Boston University's Center for Computing and Data Sciences are examples of projects where applying these technologies is possible and valuable. Being inclusive of the physical structures, green structures play a critical role in addressing modern environmental issues; in return, they embrace economic and social sustainability for a better ecological future.

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