The Bio-adaptive algae contribution for sustainable architecture

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Abstract. By studying nature, engineers, architects & designers can gain inspiration for designs that have never existed before; therefore applying bio mimicry can affect our buildings. For every problem that we currently face – whether it is generating energy, finding clean water, designing out waste, adapting with surrounded climate or manufacturing benign materials - we can use the different applications of biomimicry to achieve sustainable futuristic design approaches. The focus of this paper is on the use of algae as a promising bio sustainable way to achieve sustainable architecture. According to its high ecological performance, algae provides multi solutions towards improving the environment and opens a new perspective in sustainable design through its combination of carbon neutral energy production and recycling of environmental pollutants. By clarifying the challenges and future technology development for introducing algae as living elements into the built environment to make an appearance in many building plans that attempt to achieve visionary design and face technical challenges that need to be resolved to enable wider adoption. Therefore, this research aims to demonstrate how to use biomimicry to enhance sustainable solutions in building design and gives a glance of the algae possibilities for achieving sustainability.

Keywords: Sustainable architecture, bio-adaptation, the algae & biomimicry.

1. Introduction
The disciplines of design and architecture can extrapolate knowledge from the biological world in order to improve the way humans live [1]. This means that the extrapolated knowledge can be acquired through exploring various Biomimetic innovations and applications. Plants' new technologies offer varied possibilities for a sustainable construction and algae, in particular, acts as one of the crucial plant species that causes a successful integration in the built environment. Where Algae are gaining wide attention in the recent times especially in energy scenario as an alternative renewable source of biomass and in lowering the amount of embodied carbon.

Therefore, this paper highlights on using algae as the nature’s model and reveal how algae-powered innovations, to generate a multifold contribution for improving the health of the environment. Then clarifying the sophisticated features of algae to enhance sustainability in architecture as a key approach...
of nature’s strategy. Moreover, analyzes some architectural applications, which clarify the benefits of using algae as one of the bio promising sustainable way to outline a theoretical framework towards sustainable solutions in architecture.

2. Methodology
This paper depends on qualitative research study adopting the characteristics of an inductive and analytical approach. The methodology of this research is consists of three-step process ‘Figure 1’.

First, a literature review which it considers a research background about the algae as one of the most biomimetic elements, which are promising sustainability especially in architecture. Second, an analytical study for different applications will presented and analyzed in terms of usage algae to provide insights of the current algae technologies, which can achieve sustainability in architecture. Finally, suggest a proposed framework to determine the guidelines of the relationship between sustainability and architecture through using algae by infer many contributions that divided according to the three main pillars of achieving sustainable building issues “Environmental attributes Economic attributes and Social attributes”. A subsection

Some text.

Figure 1. The research method "by authors".

3. Research Background

3.1. Historical evolution of using algae
Early in the history of life, algae changed the planet’s atmosphere by producing oxygen, thus paving the way for the evolution of eukaryotic organism [2]. As shown here ‘Figure 2’. moving from ancient times to the present, the algae remain more important than most people realize.

Figure 2. The evolution of using algae "by authors".

3.2. Scientific classification of algae species
Generally, algae are categorized into two groups microalgae and macro-algae based on their morphological features and size. And Microalgae is considered a diverse group of photosynthetic
microorganisms that convert carbon dioxide into valuable compounds including biologically active compounds such as biofuels, foods, feed and pharmaceuticals [bioactive-compounds] [3, 4]. As well as the frequently used micro-algae are classified under four main groups i.e., Cyanophyceae (blue-green algae), (green algae), Bacillariophyceae (including the diatoms) and Chrysophyceae (including golden algae). See ‘Figure 3’ for different types of algae.

3.3. Algae and sustainability

Have you ever thought of algae as a central base of achieving sustainability? The algae have distinctive features that play an important role in the three pillars of sustainability. Some of these features - the continuous growth of algae as its number doubles every few hours [5], the possibility of its growth anywhere, the growth of algae in a variety of ways using a variety of methods that will create a large number of jobs’ opportunities, algae's industrial production of useful products such as plastics, chemicals, feedstock….etc., the usage of algae as an animal feed, and finally its contribution as one of high yields of biofuels as a result of storing energy in form of oils and carbohydrates - can contribute significantly to the realization of balance between cost and true value, this in turn leads to achieving sustainability through one of its pillars "economic sustainability". Economic sustainability depends highly on power saving which suggests why algae is economically important as algae produces energy almost 30 times less expensive per unit than energy generated by photovoltaic technology[6].

Another features - the abilities of the algae which are based on the photosynthetic, where they are one of the major focuses for sustainable biofuel production and CO2 consumption. Where algae show a higher photosynthetic efficiency and oil production. Today, the production of oxygen by algae (ca. 50% of all oxygen production). So these features can refer to the creation of inclusive, secure and healthy communities which it means achieving "social sustainability", as well as achieving "environmental sustainability" - which consider the first pillar of sustainability- through using less, and storing more naturally. By minimizing our reliance on electricity, gas and other fuels should be considered. Similarly recycling, harnessing and storage of energy and water also contributing factors [6]. See ‘Figure 4’ achieving sustainability through using algae in general.

![Figure 3. The four main groups of micro-algae [2].](image)

![Figure 4. The four main groups of micro-algae [2].](image)
4. The benefits of using algae in architecture

There are different methods for cultivation of microalgae which divided into main methods: open raceway ponds or closed photo bioreactor system "tubular photo bioreactor- flat panel bioreactor – Helical PBRs" [10], whereas the closed system has undergone great development over the past years specifically in the field of architecture. In this sense, as shown in chart ‘Figure 5’ the benefits of using algae in architecture are a set of contributions, these contributions divided into Environmental, economic and social attributes of algae building technology, which are considered the three main pillars of achieving sustainable building issues of sustainability in buildings [5,7 & 8].

![Figure 5. Sustainable building issues related to use algae [authors].](image)

5. Effective sustainable solutions through algae's applications in architecture

Recently, algae applications have emerged as an integral part of the building with the aim of achieving the highest efficiencies, whether through saving energy, wastewater reuse or air purification. So this session of the research clarify in more details the various uses of algae in architecture by analyzing different models of algae applications.

5.1. Integrate harvesting & product extraction in the building

The green energy can be created locally in an interesting way. Like using “GREEN ROOMS”, [9, 10&13] though we are looking for innovative design ideas to be eco-friendly from our closest living environment and it may only be the solution to be ecological stress-free. As shown in ‘Figure 6’.
5.2. Applied of an algae facades system

Algae may be growing up as an energy source, for example, see ‘Figure 7’. A new apartment complex in Hamburg, Germany, [9, 10 & 11] intends to generate heat, and it has a high-tech facade, all of these depends on the revenue from growing the micro-organism but it is actually a vertical algae farm.

As well as the bioreactors can have any shape but it has limitations on how large one panel can be, often there are two glass plates which contain the microalgae in between and it can control on the degree of required transparency. However, different setups are possible which creates different ambiences inside the building and appearance from the outside.

**Figure 6.** The Algae Room by studio Jonand Nina "Tokyo Designers Week 2009".

**Figure 7.** Using algae as an energy source inside the facades in Hamburg, Germany.

The double-skin façade as shown in ‘Figure 8’ serves as a vertical farm of microorganisms. They act as thermal regulators optimizing energy performance in the building that depends on the time of day, because they are more or less opaque according to the density of the biomass, thus it serves as a dynamic solar shading device. So using the algae facades is considered the key player of higher thermal performance, efficient reuse of wastewater and CO2 generated by the building to create health environment and more sustainable [9,11].

**Figure 8.** Using algae as an energy source inside the facades in Hamburg, Germany.
5.3. Transparency and sun shading
Shades can be formed in the buildings through using algae according to the type of system which is used. When using panels, the concentration of microalgae in the bioreactor influences on the transparency due to the absorption of microalgae for more light and this confirms the existing of inverse relationship between the concentration of microalgae inside the panels and the degree of achieved transparency.

In the other hand, when using tubes; the different of tubes' diameters influences on the transparency also. Where it can be created the colorful shading when the diameters of the tubes are bigger but it can be created the dark shadows when the diameters of the tubes are smaller [9, 10 & 12]. Different setups will influence on creating different degrees of transparency and the effectiveness of the sun shading. As shown in ‘Figure 9’ (a) & (b).

5.4. Light sources
For example, seen in ‘Figure 10’ a design of the street lamp which it depends on flooding the microalgae with sunlight to perform photosynthesis effectively and the mechanism of this design in turn depends on the existing of some opening which used to pump Carbon dioxide from them to a chamber with glass walls. As well as in ‘Figure 11’. in Denmark, "IKEA’s external future-living lab" has erected the ‘algae dome’, a four-meter-high pavilion capable of growing what could be ‘the super crop of the future’, in this example it is used the closed bioreactor system called "Helical PBRS" which consists of some spiral tubes that can form the dome, this system able to increase the production of microalgae extremely. So in general the algae lamp takes advantage of the organisms’ photosynthesis, since its battery recharges using some of the energy produced in the process. Therefore, as long as the lamp has a supply of carbon dioxide and gets some sunlight, the battery can be charged [9, 10 & 12].

So the following table 1 illustrates each application individually and its crucial role for achieving different principles of sustainability in architecture.

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| Figure 9 (a). The levels of transparency depending on the concentration of algae | Figure 9 (b). The levels of shades depending on the diameters of tubes |

| Figure 10. the design of an algae street light [P.Horvath via design boom] | Figure 11. The design of an algae street light [P.Horvath via design boom] |
Table 1. Achieving sustainability through the applications of using microalgae.

| Algae applications in architecture | Sustainable building issues |
|-----------------------------------|-----------------------------|
| Light sources                     | Economic attributes         |
| Transparency                      | Environmental attributes    |
| Algae facades                     | Social attributes           |
| Integrate harvesting              | Using the building’s waste  |
|                                  | On-site energy generation   |
|                                  | Waste water bio treatment   |
|                                  | Grow algae biomass in buildings |
|                                  | Decrease in pollutants & humidification |
|                                  | Provide thermal insulation  |
|                                  | Provide acoustic buffering   |
|                                  | Improve the carbon footprint |
|                                  | Achieve better quality of air |
|                                  | Harmony with natural environment |
|                                  | Employing biomimicry strategy |

Integrate harvesting & product extraction in the building
Applying algae facades system in buildings
Creating Transparency and sun shading
Designing light sources

Economic
Environmental
Integrate harvesting & product extraction in the building
Applying algae facades system in buildings
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● certainly achieved
● probably achieved

6. Results
So briefly, it can be integrates successfully the algae into the built environment to achieve different principles of sustainability inside the building. Moreover, it's in turn consider an important step to get an in-depth overview of the different issues perceived by various built environment stakeholders with regards to algae building technology. Therefore, it's possible now to create a proposed framework based on the different contributions, which related to the three pillars of sustainability through using algae as one of the biomimetic elements as shown in ‘Figure 12’.

![Figure 12](image_url)

7. Conclusion
This research considers one of the scientific researches that provided more complete understanding of the correlation ship between sustainability, architecture and biomimicry. And emphasize the common
element between them which is the environment. Where the environment has an important role when the architecture needs to achieve sustainable principles inside the building, also biomimicry gives us the great opportunity to offer new and inspirational solutions while creating the possibility of sustainability in the built environment.

Current findings suggest that the positive consequence of using algae which is considered one of the natural organisms inside the surrounding environment and as one of the most promising ways for achieving sustainability in architecture which it plays a serious role than most people realize, especially for sustainable biofuel production and CO2 consumption. In spite of, the relationship between using algae and creating sustainability in architecture is still not widely used. But there are many applications for using algae to grow in buildings, whether through integrating harvesting and product extraction in the building, or using algae in order to save energy, high thermal performance or as a source of lighting inside the different buildings.

Once it has been a clearer understanding of different architectural applications which are using algae to gain meaningful inspiration for enhancing innovative sustainable solutions, a proposed framework has been suggested to clarify the different contributions, which related to the three pillars of sustainability through using algae as one of the biomimetic elements.

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