Microalgae in architecture as an energy source

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Abstract. Microalgae possess unique properties: in the course of their life, microalgae, through the absorption of carbon dioxide, sunlight and nutrients, carry out the process of photosynthesis and turn into biomass. Biomass is further processed and many types of products are produced from it, such as oils, nutraceuticals, livestock feed, fertilizers and other substances. Some of them can be used as a renewable energy source, for example, for the production of biofuels. The production of biofuels using biomass as a renewable energy source, which is an inexhaustible source for solving the energy problem, is becoming increasingly important. The use of algae in architecture has brought many benefits, such as energy saving, reducing carbon dioxide emissions, oxygen generation, biofuel production, wastewater treatment at the micro level using building facades and at the macro level by integration into urban space. This article analyzes the problems associated with these aspects and proposes their solutions, which must be taken into account when further integrating photobioreactor systems into architecture.

1. Introduction

Today it seems impossible to live in a world without energy, its constant use has become an integral part of our lives. Most of the energy comes from fossil fuel sources, the burning of which causes environmental pollution and climate change. At the same time, a large amount of carbon dioxide is released into the atmosphere [1]. Fossil fuels, especially oil, coal and natural gas, provide about 85% of our energy needs worldwide. The biggest problem with fossil fuels is that they are the ultimate source, and they are in danger of disappearing in the near future. Today, traditional sources of energy, such as oil and coal, etc., are used to a greater extent than renewable sources of energy. To achieve a reduction in carbon dioxide emissions, the use of renewable energy sources such as nuclear energy, solar energy, geothermal energy, wind energy and microalgae biomass energy is inevitable [2]. Unlike fossil and nuclear fuels, alternative energy is provided by eternal natural sources (wind, sunlight, geothermal energy and microalgae biomass). Using these resources to meet our energy needs supports sustainable development by reducing greenhouse gas emissions. The development and use of renewable energy...
sources will bring significant benefits to all countries of the world, including energy production, environmental protection, pollution reduction and the development of modern technologies.

With the growing energy consumption in the world and the depletion of fossil fuel reserves, we must be sure that in the near future we will be ensured energy security when traditional sources of energy are exhausted. Currently, the energy we use comes from fossil fuel sources, and when it is produced, greenhouse gas CO2 is released, and then it is transported over long distances. In this regard, energy needs local production from a sustainable source. Buildings contribute 30% of the total energy consumption, and therefore, if buildings can generate their own energy, this will have a big impact on its total consumption. Currently, wind generators and photovoltaic panels are popular energy-saving installations. These systems can sustainably generate electricity, but they cannot consume carbon dioxide to lower their level. Microalgae can simultaneously reduce CO2 emissions and produce energy [3].

2. Materials and methods
Numerous parameters affect algae cultivation and the lipid content of algae affects the biomass harvested. Photosynthesis is a reaction that provides the first conversion of sunlight into energy. Consequently, all the components involved in photosynthesis contribute to the growth of algae. CO2, water consumption, supply and concentration of nutrients (nitrogen, phosphorus), light, O2 removal, temperature, pH and salinity. In addition to environmental parameters that can photosynthesis of microalgae to efficiently collect microalgae, operating parameters are also very important. [4] These operational parameters relate to the conditions for growing microalgae in the photobioreactor system. Lighting, mass transfer, mixing, dilution coefficient, collection frequency, scaling, process control and cleaning are important operational parameters to create optimal conditions for growing microalgae.

The fuel component is converted into biodiesel, and the remaining biomass can be used for fertilizers, animal feed and other auxiliary products. The nutrients in the system are removed from the water and processed to produce biomass. [5] A portion of the biomass used is used to produce electricity that is consumed during biomass production or for biogas production by anaerobic digestion. Excess electricity can be stored in batteries or sold by the city network. Photovoltaic cells can also be used to protect the electricity generated by the microalgal system. Anaerobic digestion waste can be used as a nutrient-rich fertilizer. Hydrogen gas is also released from the microalgal biomass. But as a source of hydrogen, microalgae are still under research and development.

Oil is obtained by drying microalgae. After oil extraction, anaerobic fermentation of algae sludge with a high content of organic substances is carried out. Thus, biogas energy is obtained due to the high content of organic substances in microalgae used for the production of biodiesel [6]. Converting biogas to biogas produces electricity that can be reused for growing microalgae. Thus, biodiesel, biogas, animal feed and electricity are generated from microlites at the same time.

3. Results and discussions
According to studies, biomass energy is considered the main source of renewable energy, as it has significant advantages over others. For example, it is available all over the world, it is relatively simple to process, without requiring expensive equipment, in addition, it can be stored for a long time and reused. To produce biomass energy of the first generation, which is considered an alternative to traditional fossil fuels, by producing biodiesel from oils extracted from various land plants, such as soybean, sunflower, palm, corn, coconut and others, large agricultural areas are needed. [7] Thus, the use of agricultural land with a limited area capacity and a limited capacity of fuel obtained from agricultural products, which form the basis of the fuel product, makes algae more productive among other types of biomass [8]. To reduce the use of agricultural land, as well as to reduce the cost of transporting fuel, it is proposed to use buildings and urban space for the implementation of these energy sources. New types of photobioreactors make it possible to convert even more natural resources into energy. By incorporating this system into architecture, we get buildings that are independent of the city...
network. Autonomy will create safe conditions for medical facilities in case of interruptions or natural disasters, as well as more comfortable conditions for living in an urban environment [9]. Despite the fact that photovoltaic solar panels and wind turbines as integrated renewable energy sources are very common in architecture, algae biomass as the most efficient source has limited use in this area.

Microalgae-based photobioreactor systems are typically used in architecture in three different ways: to create integrated photobioreactors as a second facade, to form holistic urban spaces, and to create individual small architectural forms of microalgae [10].

The use of a photobioreactor integrated in building facades.
1) B.I.Q House, Hamburg, Germany (Figure 1).
2) Photo.Synth.Etica, Dublin, Ireland.
3) Process Zero Concept Building, Los Angeles, California, USA.

![Figure 1. B.I.Q House, Hamburg, Germany.](image1)

The formation of integral urban spaces.
1) Carbon T.A.P. (Tunnel Algae Park), Philadelphia, USA (Figure 2).
2) Culture Urbaine, Geneva, Switzerland.
3) AlgaEnergetyCity, Istanbul, Turkey.

![Figure 2. Carbon T.A.P. (Tunnel Algae Park), Philadelphia, USA.](image2)

Separate small architectural forms based on microalgae.
1) Urban Algae Canopy, EcoLogicStudio (Figure 3).
2) Street lamp, Pierre Callech.
3) Living beings, Jacob Dunias and Ethan Frier.
4. Conclusions
Throughout the evolution of the architectural environment of the city, gardening has largely determined the quality of urban areas under the conditions of modern super-urbanization of the urban environment, the resource for the formation of parks and city squares has been practically exhausted [10]. The greening of the buildings themselves often also cannot completely neutralize the negative impact of anthropogenic factors, and offset the reduction in the productive surface of the Earth. Under these conditions, one of the promising technologies is the integration of microalgal cultures into urban spaces. According to a number of indicators, this technology is four times more effective than conventional landscaping methods, which allows almost completely preserving the productive potential of territories alienated from nature, devoting 75% of the site area for construction.

Thus, using photobioreactive systems as a second facade in buildings and targeted implementation of them in architecture at micro and macro levels, it was noted that this integration has many advantages, such as energy saving, oxygen supply to the air, and reduction of carbon dioxide emissions into the atmosphere, biofuel production and wastewater recycling. This situation demonstrates a holistic approach to sustainable development, which can cover the whole city with the integration of photobioreactors developed using microalgae. Their unmatched benefits through a combination of technical, biological, and chemical cycles in architecture begin an innovative approach to architecture using renewable energy sources by integrating the values of ecological architectural design and shed light on future research.

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