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Building the future with algae

How algae building technology can generate on-site renewable energy and be used in building materials

Author: Prof. Sara Wilkinson, Prof. Peter Ralp
h and Prof. Arnaud Castel **13 October 2020**

Energy Technology Building surveying

Algae grown in the University of Technology, Sydney science faculty IMAGE © UTS

A major environmental impact of humans is the emission of greenhouse gases (GHG) which contribute to the greenhouse effect whereby global temperatures increase and the Earth warms. Buildings, and the energy used therein, contribute around 40% of total GHG emissions and reducing building-related GHG emissions could help to mitigate global warming. However, there are many political, economic, social, technological, legal and environmental factors that hinder the uptake of measures to mitigate GHG emissions globally.

One proven technical option is to increase building energy efficiency; but the uptake is variable. Renewable energy sources such as wind, wave and solar power are viable options. Renewable energy - and bio-energy - offers great potential, and is predicted to dominate energy production in the 21st century. In 2014, with worldwide biomass energy production at 88GW it was claimed that bio-energy is no longer in transition in terms of volume. However, building surveyors currently know little about bio-energy.

Algae are capable of producing oxygen through photosynthesis, which is the process of harvesting light energy from the sun to generate carbohydrates, lipids and proteins. Algae are a diverse group of aquatic organisms that include seaweeds such as kelp, phytoplankton, pond scum or algal blooms in lakes.

Algae are a source of bio-energy that can be used in buildings. In 2013 Arup, designed the BIQ House in Hamburg, Germany, adopting a novel approach by using what is now known as algae building technolog. Building envelopes and facades have a major role in energy performance. There are estimated to be 300,000-500,000 algae species, the BIQ building used Haematococcus pluvalis.

The BIQ House: the first algae-powered building, IMAGE © COLT INTERNATIONAL

This particular species of algae grows as a suspension, not a biofilm. Those algae that grow as a biofilm would need to be scrapped off the window surface, whereas algae in a suspension can be harvested from the water. Many types of algae could grow in the panel – temperature and light are the main criteria for selection. Haematococcus makes a pigment called astaxanthin which is a strong antioxidant.

additional dead loads to the structure and this needs to be factored in.

Hamburg has a cool climate. The BIQ consists of 15 apartments, each with 50-120m^2 space, on 4 floors. Two forms of energy are produced. Algae is grown in 120 triple-glazed storey-height façade panels called integrated photo-bioreactors (PBRs) totalling 200 square metres, on 2 façades. The PBR panels move horizontally across the balconies to create a thermally- controlled microclimate around the building, reducing unwanted external sound transmission and providing dynamic shading. The external walls are a Passivhaus low-energy design. Construction costs, at approximately €5m, were higher than conventional apartment construction.

As part of the photosynthesis process, algae produce oil and can generate up to 15 times more oil per acre than other terrestrial plants used for biofuels, such as corn. Also, algae can grow in salt water, freshwater or even contaminated water, in the sea or in ponds, on land not suitable for food production, as well as in building façade panels.

Sustainable algae production can deliver biofuel as well as food, while raising environmental standards and arable productivity in farming sectors around the world. They reduce the use of fossil fuels associated with GHG emissions, and advanced biofuels from cleaner feedstocks offer greater environmental benefits.

“Photo-bioreactors, glazed storey-height panels filled with algae in water, generate biomass and solar thermal energy”

highly efficient for algal growth and are designed to require minimal maintenance. They are constructed with 4 glass layers: a pair of double-glazing units creating a cavity, filled with argon gas to minimise heat loss.

Algae are cultivated in the PBRs where sunlight and constant turbulence, delivered by mixing air and carbon dioxide to maintain appropriate pH levels, causes the algae to grow producing a food source. There is potential to use grey water if it contains phosphorous and nitrogen that needs to be removed. The liquid in the PBRs is heated and recovered by a heat exchanger for heating hot water and central hydronic heating. The biomass is transported via pipework to an onsite energy management centre, where it is harvested and the biomass paste is moved to separate processing facility for conversion to biofuel or other uses such as fibre or feedstock, if desired. Regular maintenance and flushing of the system is required to ensure flow rates are not reduced.

The heat produced by solar thermal energy has 38% efficiency, compared to 60-65% in conventional solar thermal sources, and the biomass has 10% efficiency compared to 12-15% with conventional PV installation. So, this technology is not yet as effective as other sources of renewables such as solar. The algae sequesters carbon dioxide and the 200-square-metre PBR façade removes up to 6 tonnes of carbon dioxide annually.

geothermal boreholes. A unit is operated to provide the carbon dioxide nutrient (flue gas) required by the algae in the bioreactor façade and to cover the supply of hot water at 70°c or heating in the energy network.

The biomass grown generates energy around 30KWh/m^2/yr and is harvested every 3–4 weeks through an algae separator. Around 80% of the biomass harvested in the BIQ Hamburg is converted into methane at an offsite, outdoor biogas plant and returned to the building for electricity and heat generation.

Water temperature

PBR water temperature is controlled by the speed of fluid flowing through the panels, for example, lower flow rates allow more time for sunlight to warm the water passing through. The amount of heat extracted via heat exchangers in the central plant affects the PBR water temperature. Maximum PBR temperature is around 40°c, as higher temperatures could harm or kill the algae. However, this relatively low maximum PBR temperature limits the practical use of the extracted heat to mainly a pre-heating function for other building systems. In a warmer climate than Germany this might not be the case.

Total energy system conversion efficiency is 27% relative to the full available solar radiation incident on an unobstructed building roof. When sited optimally to capture total available solar radiation, PV systems have an efficiency of 12-15%, whereas solar thermal systems are 60-65% efficient. The BIQ total energy conversion of the algae system is lower than conventional solar hot water panels. However, the bio-responsive façade delivers energy directly to several building services systems, and delivers supplementary energy benefits such as shading during the summer and the biomass for conversion to biofuel. Therefore, on a total cost-benefit analysis of tangible and intangible costs and benefits, the overall outcomes might be positive; however, this is currently unknown.

contractors, quantity surveyors, certifiers, property managers and facility managers. If key stakeholders lack knowledge and understanding, the take up of this technology will be affected negatively.

On this basis, we undertook a feasibility study to ascertain the perceptions of those key stakeholders and built environment professionals to ascertain their views with regards to pros and cons of this innovative technology. In our next article, we will outline the technical issues associated with algae building technology.

Algae in building materials

Concrete is the most widely used construction material globally. Carbon dioxide emissions from the manufacture of Portland Cement is second only to that of fossil fuels and is responsible for a significant proportion of worldwide total GHG emissions. In addition, availability of quality natural sand has been declining markedly due to its excessive use in concrete. The sand exploitation rate is now far greater than its renewal. In addition, excessive mining of river sand places detrimental stresses on river biodiversity, riverbeds, river basins, salt-wedge intrusion, ecological communities and food webs.

Some species of algae can produce calcium carbonate exoskeletons, or shells. These cells capture carbon dioxide from the atmosphere and transform it into calcium carbonate, using chemicals from seawater. Carbon capture technology using algae could be implemented in cement plants to produce calcium carbonate-based manufactured sand suitable for concrete applications. This technology is a step towards reducing carbon emissions from cement production and helping to address the increasing scarcity of natural sand.

Peter Ralph is professor of marine biology at the University of Technology, Sydney

peter.ralph@uts.edu.au

Arnaud Castel is professor of civil and environmental engineering at the University of Technology, Sydney

arnaud.castel@uts.edu.au

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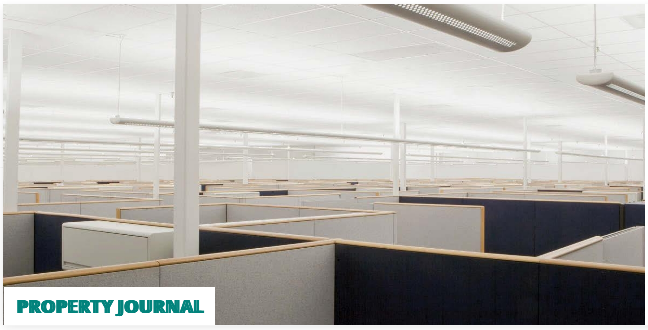

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