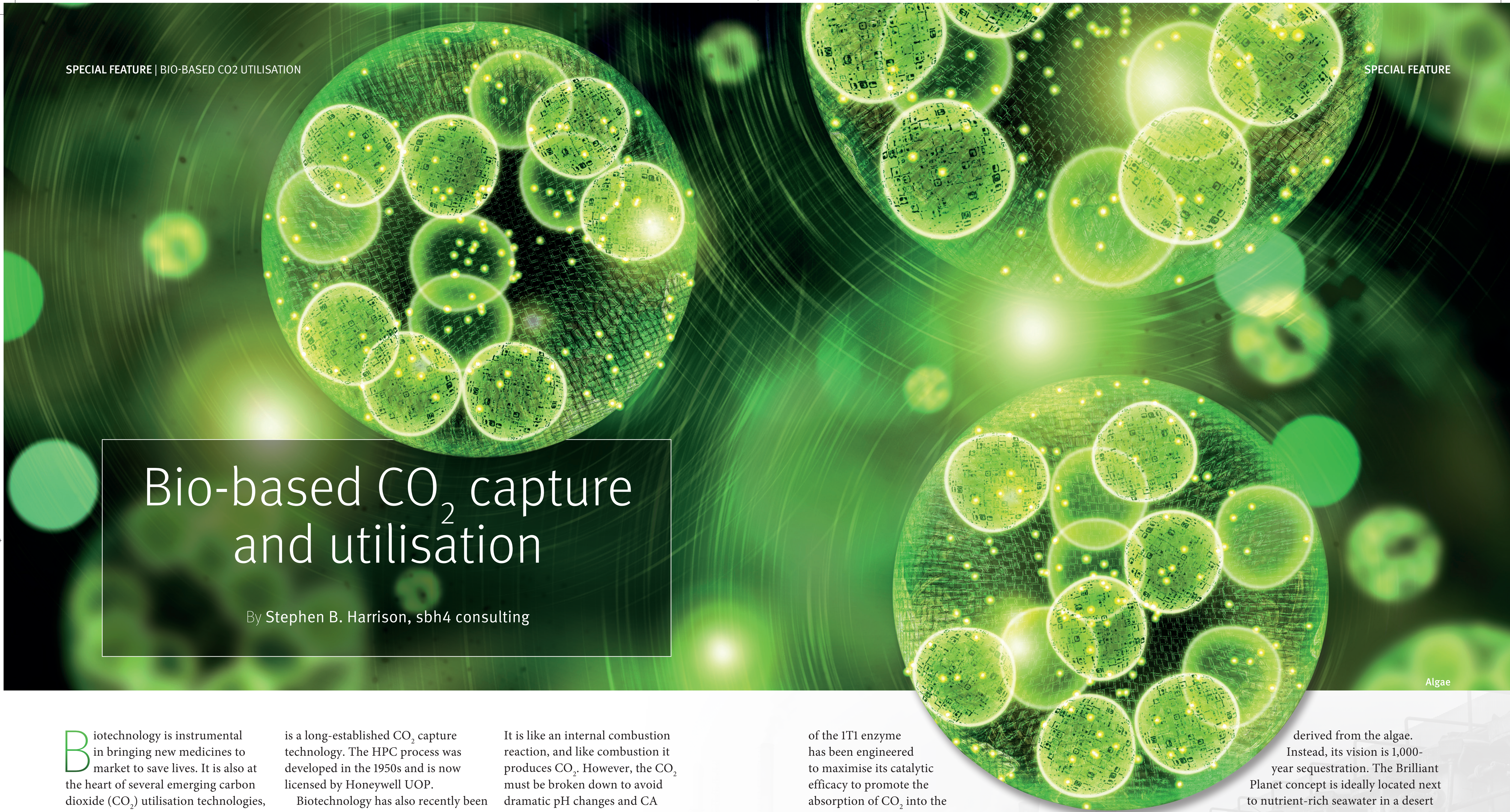


Algae

Bio-based CO_2 capture and utilisation

By Stephen B. Harrison, sbh4 consulting

Biotechnology is instrumental in bringing new medicines to market to save lives. It is also at the heart of several emerging carbon dioxide (CO_2) utilisation technologies, such as the production of nutritional supplements and the conversion of carbon to chemical intermediates such as ethanol. Ethanol can be used to make synthetic aviation fuel (SAF) and other valuable chemicals.

Enzymes for energy efficient solvent-based CO_2 capture

Hot potassium carbonate (HPC) is a long-established CO_2 capture technology. The HPC process was developed in the 1950s and is now licensed by Honeywell UOP.

Biotechnology has also recently been applied to catalyse CO_2 absorption in the HPC process through the use of carbonic anhydrase (CA). This is an enzyme which plays an essential role in humans and many animals. Its function is to remove CO_2, which is a by-product of respiration.

Respiration is the mechanism by which animals convert oxygen that they breathe and food that they eat to energy. It is like an internal combustion reaction, and like combustion it produces CO_2. However, the CO_2 must be broken down to avoid dramatic pH changes and CA supports that by catalysing the reaction of CO_2 with water to form bicarbonate and hydrogen ions:

$$CO_2 + H_2O \rightarrow HCO3\text{-} + H+.$$

A proprietary CA enzyme known as 1T1 is used by CO_2 Solutions by Saipem on industrial CO_2 capture systems. The molecular structure of the 1T1 enzyme has been engineered to maximise its catalytic efficacy to promote the absorption of CO_2 into the potassium carbonate solution and whilst also allowing low-cost manufacture of the enzyme.

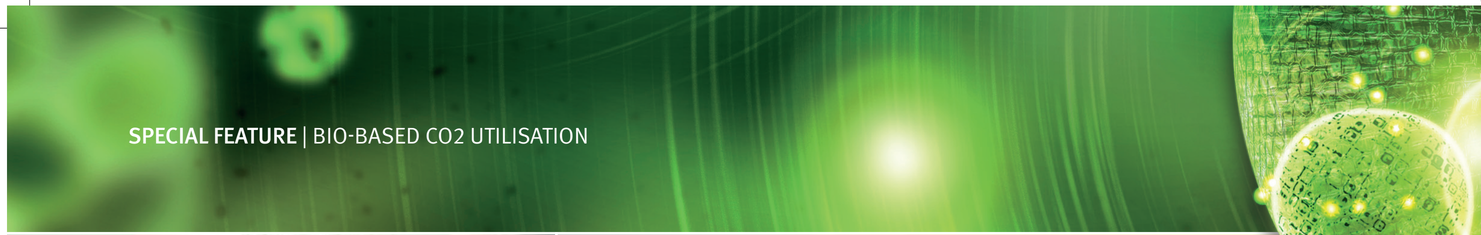
Algae for CO_2 capture

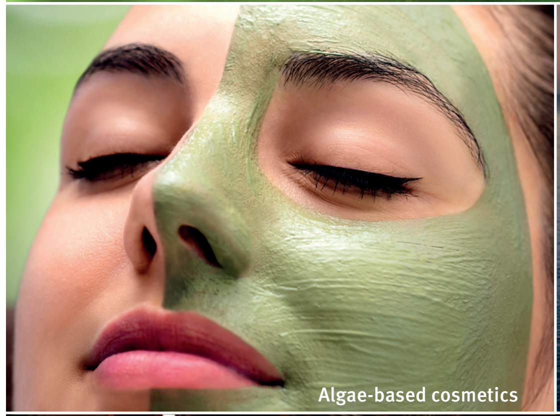
Algae use photosynthesis to grow their cell mass, however unlike trees and plants, their entire function is dedicated to photosynthesis and they do not expend energy growing physical structures. The implication is that per acre of land, they are much more efficient at capturing CO_2 than a forest.

The British start-up Brilliant Planet has also developed a CO_2 capture process that relies on algae. However, its intent is not to utilise the products derived from the algae.

Instead, its vision is 1,000-year sequestration. The Brilliant Planet concept is ideally located next to nutrient-rich seawater in a desert location. Seawater is pumped into a lagoon filled with algae. Nutrients in the seawater are absorbed by the algae as they grow. They simultaneously absorb CO_2 from the air in a form of direct air capture (DAC) of CO_2.

CO_2 capture is also achieved through a second mechanism. The algae consume bicarbonate ions from the seawater. These ions have been ▶





Algae-based cosmetics

Fish farming

Iron and steel processing

created naturally during absorption of atmospheric CO_2. As the lagoon water is released back into the sea, it re-absorbs CO_2 from the atmosphere. This is also a natural form of direct air capture of CO_2.

"...a new generation of algae technologists are turning to CO_2 capture as their business model"

The algae are harvested, dried and buried under sand in the desert. The dry, salty algae are acidic and cannot biodegrade in the desert sands. This guarantees that the captured CO_2 is permanently sequestered.

Omega-3 oils from algae for CO_2 capture and utilisation

Various types of algae are used in cosmetics and as a meat substitute in vegan and vegetarian foods. The use of pure CO_2 gas to accelerate the growth of algae in these commercial utilisation applications has been common for several years. However, a new generation of algae technologists are turning to CO_2 capture as their business model.

The Danish start-up ALGIECEL has targeted the capture of biogenic CO_2 as biogas is upgraded to biomethane from anaerobic biogas reactors. Its vision is to utilise the captured CO_2 to cultivate algae which will be rich in omega-3 oils. These can be used as nutritional supplements for humans, livestock and farmed fish.

The ALGIECEL PhotoBioReactor (PBR) is a containerised unit designed

Iron and steelmaking flue gases are rich in CO and CO_2

15%
IN THE US THE ETHANOL COMPOSITION IN FUEL CAN BE UP TO 15%

to match the scale of biogas production on many of Europe's 18,000 biogas reactors. Light for the photosynthesis is provided by energy efficient LEDs to ensure 24-hour operation at maximum CO_2 capture and conversion yields.

Bio-fermentation to ethanol

Like algae, bacteria can also consume CO_2 and carbon monoxide (CO) to produce valuable chemicals such as ethanol. LanzaTech utilises anaerobic acetobacter bacteria in a fermenter to convert CO rich feed gases, such as syngas, to ethanol and a range of biochemicals.

The ideal feedstocks for the LanzaTech fermenter are CO-rich. Iron and steelmaking yields CO-rich flue gases which are ideal feedstocks to the LanzaTech process. Blast furnace gas (BFG) contains 20% CO and converter gas (also known as basic oxygen furnace gas or BOFG) contains 60% CO.

The energy-rich converter gas (LHV 3 kWh/Nm^3) is often utilised on the iron and steelmaking facility for heat or power generation on a gas engine. Alternatively, it is often flared. Blast furnace gas has a lower energy value due to the lean CO concentration and higher CO_2 content (LHV 0.9 kWh/Nm^3). It can also be always utilised on the facility or is sent to the flare. Utilisation of the BFG in the LanzaTech process can generate valuable bioethanol.

LanzaTech's process was demonstrated at pilot-scale in 2008 using flue gases from the BlueScope Steel mill in Glenbrook, New Zealand. Since then, LanzaTech has successfully deployed its technology at two 300 tonnes per annum demonstration facilities at Baosteel Shanghai and Shougang Steel Caofeidian in China. These LanzaTech fermenters are fed with a range of iron and steelmaking off-gases including BOFG, BFG, and coke oven gas (COG).

Ethanol as a fuel and SAF precursor

The term CCT or 'Carbon Capture and Transformation' has been used to describe the LanzaTech fermentation process. It transforms captured carbon to ethanol. Subsequently, the complimentary LanzaJet process can be used to convert the bioethanol to synthetic aviation fuel (SAF) in its proprietary 'Ethanol to Jet' or ETJ process.

LanzaTech operates the Freedom Pines Biorefinery in Soperton, Georgia which uses bio-fermenters to generate ethanol and other chemicals. The LanzaJet ethanol to jet SAF production process will soon also be implemented at that location to utilise captured carbon to make fuels that can substitute aviation kerosene, a fossil fuel distilled from crude oil.

Ethanol is also a fuel component in its own right. In Europe it is blended with gasoline at either 5 to 10%. In the US, the ethanol composition can be up to 15%. In China, there is also a gasoline type fuel that is 85% ethanol with a 15% gasoline fraction. gw