CO2 bioeconomy: Creating value from carbon dioxide

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Is the CO_2 bioeconomy creating value from carbon dioxide? Dr Kang Lan Tee and Professor Tuck Seng Wong both explain

Our relationship with carbon dioxide

Carbon dioxide is frequently portrayed as the villain of climate change. A 50% carbon dioxide content increase in less than 200 years (National Oceanic and Atmospheric Administration) is a stark reminder of its role in global warming.

Scientists have also linked the rise of carbon dioxide with the greenhouse effect in the past 66 million years (Annual Review of Earth and Planetary Sciences). Beyond scientific reports, we have experienced the heat-dome scorching our summer and witnessed record temperatures in the UK, with the highest temperature recorded at 40.3°C on 19 July 2022. Is carbon dioxide to blame for climate change? Greenhouse gases trap

Earth's radiant heat from the Sun in our atmosphere keeping it from escaping into space. Carbon dioxide is just one of the greenhouse gases (CO_2, CH4, N2O, and fluorinated gases) listed in the Kyoto Protocol. While it has less 'warming potential' than methane, for example, its longevity keeps it lingering in our atmosphere for up to 1,000 years, accounting for a third of the total warming of Earth.

Our dependence on fossil fuels is a significant cause of the current climate woes. Fossil fuels have supercharged the industrial revolution to drive society's development. Coal, petroleum and natural gas remain primary resources in the global energy system today and significantly contribute to carbon dioxide emissions.

One argument is that emission is inextricably linked to economic growth. Historically, the richer developed countries emit more carbon dioxide. Countries have, however, started to decouple their economic growth from emissions. For instance, the UK's GDP has increased in the last 30 years while its emissions have fallen (Our World in Data).

The bad press on carbon dioxide has eclipsed its integral role to life on the planet. By trapping heat from the sun, carbon dioxide and greenhouse gases keep Earth's climate warm and habitable for humans and other lifeforms. Carbon is the backbone of life, comprising about 18% by the mass of our human body. It is transferred between different reservoirs by the carbon cycle.

For instance, plants produce food from carbon dioxide, which is then consumed by humans and other animals, transferring the carbon to us. Outside its role in Nature, carbon dioxide has numerous commercial applications. It is used to carbonate soft drinks, beer and wine, as an inert blanket to preserve food, and as a coolant for quick freezing.

It is also a raw material for methanol and urea production in the chemical industry. Pumped into oil wells, carbon dioxide can enhance oil production. Lesser-known applications include its use to de-caffeinate coffee and in surgical procedures like laparoscopy.

Innovations to combat climate change

Research and innovation are essential in our combat against climate change. Replacing fossil fuels with other energy sources is often the top change required to reduce emissions. Solar, nuclear, wind and biomass energy are primary alternatives.

These alternative energy sources are ‘cleaner’ as they have net-zero or very low emissions compared to fossil fuels. Solar, wind and biomass are also renewable, meaning we can have an ‘unlimited’ supply compared to the 57 years of oil reserve left (Our World in Data).

To limit global temperature rise below 1.5 °C, the UK aims to cut emissions to 78% below the 1990 level by 2035. Governments around the world outlined similar ambitions. It has become clear that this goal can only be achieved if we strengthen the ‘clean’ energy strategy with an ambitious plan to remove carbon dioxide from our atmosphere.

Carbon dioxide can be removed by plants through reforestation, sequestered in soil and ocean, directly captured from air and carbon mineralisation into solid carbonates. Most of these technologies are at the early stages of development or deployment. Cost remains a major barrier, drawing criticism to their economic sustainability.

Innovations that convert carbon dioxide into products are gaining the attention of governments and investors. These technologies create a CO_2 economy that transforms carbon dioxide from a liability into an asset, a pathway for carbon dioxide removal to become economically viable. Key categories of products include fuels, chemicals and building materials.

Carbon dioxide asset

A key advantage of using CO_2 as raw material for manufacturing is abundance. About 33 billion tonnes of anthropogenic CO_2 (equivalent to 9 billion tonnes of carbon) is produced yearly compared to ~4.5 billion tonnes of combined crude oil and natural gas. Plants and algae are widely recognised agents that “consume” carbon dioxide. Less known are the bacteria that grow on carbon dioxide.

Also called autotrophic bacteria, these living organisms capture carbon dioxide and use it to grow and synthesise other complex organic products. Their ability to double in mass within a few hours makes them faster to cultivate than plants or algae.

At the University of Sheffield, we are harnessing the natural abilities of autotrophic bacteria and augmenting their performance using synthetic biology to enhance carbon dioxide utilisation and broaden their product range.

One such project researches the transformation of carbon dioxide in the air into sustainable, biodegradable polymers that can replace fossil-based plastics. This creates new sustainable opportunities on multiple fronts: the removal of carbon dioxide, a move away from using fossil fuel as raw material, and a biodegradable polymer product to tackle plastics pollution.

Our vision is to use autotrophic bacteria as mini cellular factories and carbon dioxide as raw material to manufacture commodity chemicals, biopolymers and single cell protein for animal feed.

The scale and urgency of our climate problem necessitate the tandem deployment of various technologies. It is thus critical to continue investment across a portfolio of carbon dioxide removal technologies. Research and development, financing, government and business commitment, and clear messaging to the public are essential for cultivating early opportunities into future solutions.

Grants

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