Microalgae Potential for Carbon Utilization
A brief overview of the development of microalgae production for renewable energy.

Climate change has been a growing global concern for the past several decades. A recent Intergovernmental Panel on Climate Change (IPCC) report indicated increases in the atmospheric concentration of the greenhouse gases (GHGs) carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) over pre-Industrial levels of 40%, 250%, and 20% respectively. Annual average worldwide CO₂ emissions from fossil fuel combustion and cement production in 2002–2011 were 8.3 Gt of C, which is equivalent to 30.4 Gt of CO₂ with an average growth rate of 3.2%/yr.¹ CO₂ emissions from energy consumption continue to rise. If the trend continues in the same trajectory, energy use will increase by more than two-thirds (based on 2011 levels) by 2050; an average global temperature will rise approximately 6°C in the long term (by 2100).²³ Low-carbon energy technologies are required to significantly reduce CO₂ emissions. Carbon capture, utilization, and storage is one of the important measures to curb global CO₂ emission.

**Carbon Capture, Utilization, and Storage**

The term carbon capture and storage (CCS) is widely recognized as referring to the technology to reduce carbon emission by capturing CO₂ from major CO₂ emission point sources, such as power plants and industrial facilities, compressing and transferring, and then injecting into geological formation to permanently store it deep underground.⁴⁻⁵ CCS evolved to carbon capture, utilization, and storage (CCUS) in 2012 by the U.S. Department of Energy to strategically drive the research and development to economically utilize CO₂ for commercial processes.⁶ According to the 2012 United States Carbon Utilization and Storage Atlas—Fourth Edition (Atlas IV), there are at least 2,400 Gt of possible CO₂ storage resources in the United States. Current estimations of CO₂ emissions from power plants and industrial sources are 33% and 22%, respectively; the application of CCUS technologies at these facilities will greatly benefit the U.S. environment.

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and economy in both preventing CO$_2$ release to the atmosphere and utilizing capture CO$_2$ in the industrial processes.$^5$

**CO$_2$ Utilization**

CO$_2$ utilization has been introduced as a possible alternative and/or complement to the geological storage of CO$_2$ that could increase the economic value for captured CO$_2$. Current estimates of CO$_2$ sold annually for commercial application are 80–120 Mt.$^2$ Example applications include use as chemical solvents, soft drinks carbonation, and fertilizer manufacture. Tertiary recovery (or enhanced oil recovery, EOR) is largest CO$_2$ consumption industry, mostly from natural sources. EOR techniques can ultimately increase 30–60% more production than the reservoir original oil. Gas-injection EOR currently accounts for nearly 60% of EOR production in the United States.$^6$

As of 2014, there were 113 CO$_2$ EOR projects in the United States, injecting 3.1 billion cubic feet per day (Bcf/d) or 60 Mt per year of natural and industrial CO$_2$ for EOR. The EOR-associated crude oil production was 282,000 barrels per day in 2012. However, the growth of CO$_2$ EOR oil production has been limited in the past few years due to restrictions in accessibility to affordable supplies of CO$_2$.$^7$ The current cost of utilizing captured CO$_2$ is 5–10 times higher than naturally occurring CO$_2$ from underground reservoirs.$^8$ Other emerging applications, such as plastics production or enhanced algae cultivation for chemicals and fuels, are still in the developmental stages.$^2$

**Microalgae Production**

In the past decade, there has been increased interest in the development of microalgae production for renewable energy supply. Microalgae are photosynthetic microorganisms that can grow rapidly. With abundant solar energy, during photosynthetic activities, microalgae consume CO$_2$ to reproduce their cells and store energy in the form of oils, carbohydrates, and proteins. Advantages of microalgae biofuels are greater production yields per land area compared with terrestrial crops, such as corn and soybean. Microalgae production does not require arable land, hence it does not compete with food crops.

Algae biomass production is estimated to produce 2–10 times more biomass per unit area than the best terrestrial systems. The main reason for this is greater photosynthetic efficiency. Under ideal growth conditions, algae use most of their energy in cell division allowing for rapid biomass accumulation.$^9$ Approximately 1.8 tons of CO$_2$ is required to produce 1 ton of algae. By contrast, some estimates have shown that 0.63 Gt of CO$_2$ is required to produce 1 million barrels of gasoline.$^{10}$

**Pilot Project**

A pilot renewable energy project has been designed and constructed at the University of Cincinnati to study the production of microalgae utilizing the CO$_2$ from biogas content. The biogas is derived from an anaerobic digester designed to convert food wastes from the University of Cincinnati’s cafeterias into usable energy. The microalgae production system was designed as closed system using continuous flow stirred tank reactor (CFSTR) with bubble column to transfer CO$_2$ into growth media. The system will demonstrate the economical setup...
of microalgae production in pilot scale, as shown in Figure 1. This setup can also be used with other CO₂ source such as captured CO₂ or can be constructed with any CO₂ source with small area requirement.

**Conclusion**

In 2013, biofuels such as ethanol and biodiesels contributed to only about 5% of total energy used by the U.S. transportation sector. Large-scale production of microalgae as a source of biofuel will potentially be another technology utilized carbon captured from CCUS. However, many challenges remain in the research and development of microalgae production, including identifying fast growing and tolerance strains, enhancing photosynthetic efficiency, contamination control, recycle growth media and nutrients, lowering harvesting, and conversion cost.

**References**