Anaerobic bioprocesses towards the conversion of carbon dioxide into bio-based products: a short review

Anna Zuliani, Riccardo Lo Coco, Giovanna Pesante, Federico Battista, David Bolzonella, Nicola Frison

Department of Biotechnology, University of Verona
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Global Greenhouse Gas Emissions


Daily CO\textsubscript{2} concentration in the atmosphere

Jun. 7, 2022  421.42 ppm
Jun. 7, 2021  419.80 ppm
1 Year Change  1.62 ppm (0.39%)
From waste to new resources

- Carbon neutrality by 2050

- Waste, wastewater and activated sludge represent biomass and potential untapped resources

- These can be converted into bioenergy and bio-based products through conversion bioprocesses

- Green Revolution and Ecological Transition
EU Emission Trading System (ETS)

- Mitigation of carbon dioxide (CO₂) emissions

- Reduce emissions through systems that capture them

- The EU Emissions Trading System (ETS), sets a price for carbon and reduces the cap applicable to emissions from certain economic sectors each year

CO₂ market price: around 90 €/ton
Carbon capture, use and storage

Capture
Capturing CO₂ from e.g. biomass-fuelled power stations, industrial facilities or directly from air.

Transport
The compressed CO₂ is moved by ship, truck or pipeline from point of capture to the point of use or storage.

Use
Captured CO₂ is used as a resource or feedstock to create products and services.

Storage
Storing the CO₂ permanently in underground geological formations.

https://ec.europa.eu/clima/eu-action/carbon-capture-use-and-storage_es
Carbon dioxide capture/sequestration and conversion

- **Capture/sequestration**: geological confinement process of carbon dioxide (CO$_2$) produced by large combustion plants

- **Conversion** (transformation) of CO$_2$ into new bio-products of interest
Capture of carbon dioxide through different physicochemical methods
Bioconversion of carbon dioxide into bio-based products

Bio-based products:

- Building blocks (e.g., VFAs)
- H₂ & CH₄
- Biodiesel
- Polyhydroxyalkanoates (PHAs)
- Bio-oil
- Single cell proteins
From waste to new products

Chemical Processes:
\[ \text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O} \ \Delta G^0 = -113.5 \text{ kJ/mol} \]
using Ni catalyst

Biological Processes:
\[ \text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O} \ \Delta G^0 = -130.7 \text{ kJ/mol} \]
From waste to new products

Purple phototrophic bacteria are versatile microorganisms with multiple metabolisms:

- CO$_2$ can be converted into several bio-based products
- N$_2$ fixation can be accomplished during CO$_2$ conversion
Anaerobic biorefineries
Technical/economical/legislation barriers

- Lack of technical expertise due to long industry chain
- Resource usage at scale: removing 1 GtCO₂ could consume as much as 1.4x the total electricity generation for the EU in 2018
- Technology performance: CCS still in developing phase with uncertainty in performance
- CAPEX uncertainty: immaturity of CCUS & uniqueness of industrial sites limits replicability & cost estimation
- OPEX uncertainty: uncertainty of future oil prices
- Risk perception: investors require high ROI due to high risk
- Lack of revenue model: due to low CO₂ prices & insufficient utilisation opportunities
- Uncertainty in demand: for industrial products
- Public resistance: often because of lack of knowledge
- Policy uncertainty: lack of comprehensive frameworks and business models to facilitate CCUS
- Regulations & infrastructure: admin causes 5-10 year delays and slow the pace of construction
- Cross-chain integration: many uncertainties in coordination between many stakeholders, volume risk of CO₂ & CO₂ reliability transfer

https://ec.europa.eu/clima/eu-action/carbon-capture-use-and-storage_en#barriers
Thank you for your attention