Techno-economic comparison of CO_2 valorization through biotechnological and catalytic conversion

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Introduction

Carbon dioxide (CO_2) emissions have a significant impact on climate change and global warming with concentrations reaching 400 ppm in recent years [1]. Besides, international organizations have committed to measuring greenhouse gas (GHG) concentrations and to striving to achieve carbon neutrality and clean production models in alignment with the SDGs and Planetary Boundaries.

Various technologies exist for CO_2 valorization in industrial facilities known as C1 biorefineries where CO_2 is considered as a raw material for upgrading technologies to reduce GHG emissions [3]. Production processes can reach energy efficiency by implementing C1 biorefineries to allocate CO_2. Thus, considering the growing interest in CCU, as well as the utilization of renewable resources (i.e., biomass) for value-added products and energy generation, this research focuses on analyzing CCU alternatives under the C1 biorefinery concept.

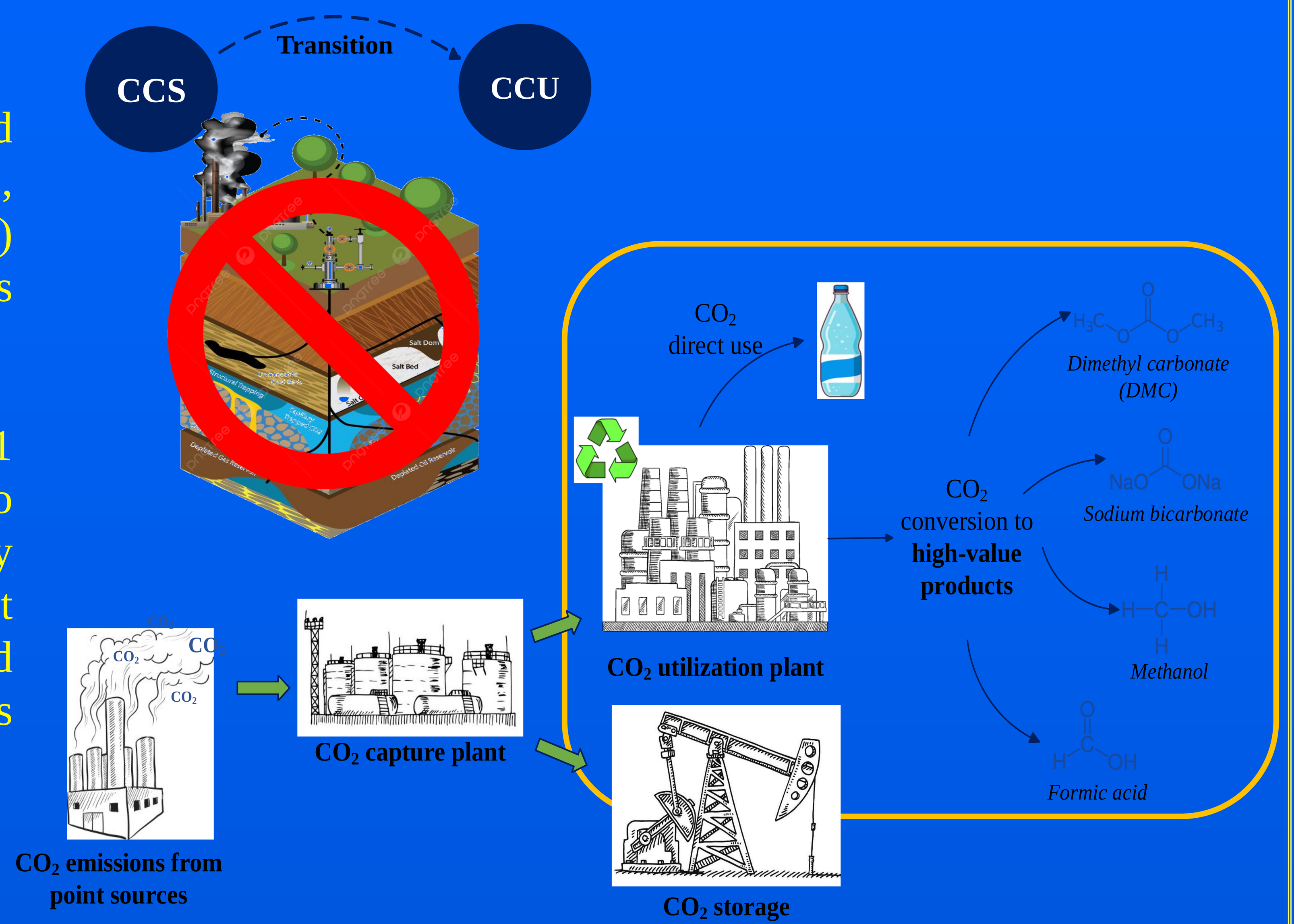


Figure 1. Proposed scheme of C1 biorefinery [2].

Methodology

CO_2 was considered as a raw material for the obtaining of methanol through catalytic conversion and ethanol through biotechnological conversion. CO_2 was fed as a pure component after being captured from the flue gases of a natural gas-based reboiler operated for biomass upgrading.

The biorefineries schemes were simulated in the software Aspen Plus v.9.0.

The simplest valorization schemes (stand-alone) are shown below. However, different integrations could be analyzed under the C1 biorefinery concept.

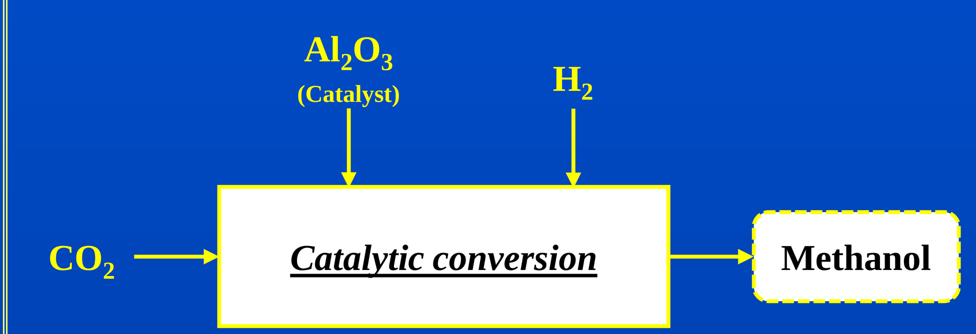


Figure 2. Block diagram for methanol production through hydrogenation.

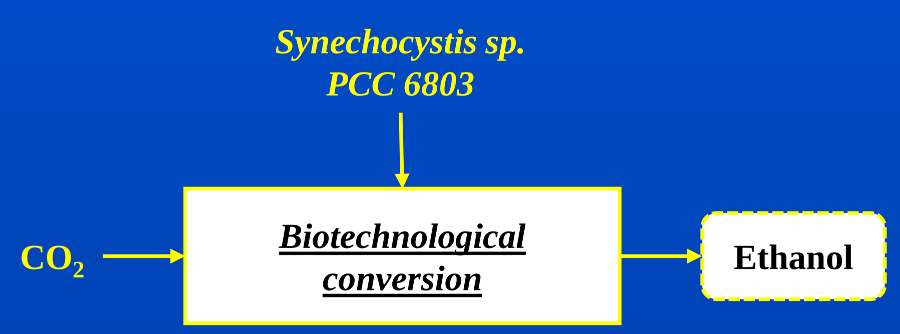


Figure 3. Block diagram for ethanol production using *Cyanobacteria*.

Technical indicators

- Product yield (%):

$$Y_P = \frac{\sum_{j=1}^{N} \dot{m}_j^{product}}{\sum_{i=1}^{N} \dot{m}_i^{in}} \cdot 100$$

- Ratio $CO_{2,out}$ / $CO_{2,in}$:

Vales less than 1 indicate that the amount of **CO_2 emitted is less than the CO_2 fed** to the process.

Economic metrics

- Sizing

Aspen Process Economic Analyzer v.9.0.

- OpEx

Raw material costs, supplies, and utilities.

- Cash flow and scale analysis

- Net present value (NPV).
- CapEx.
- OpEx.

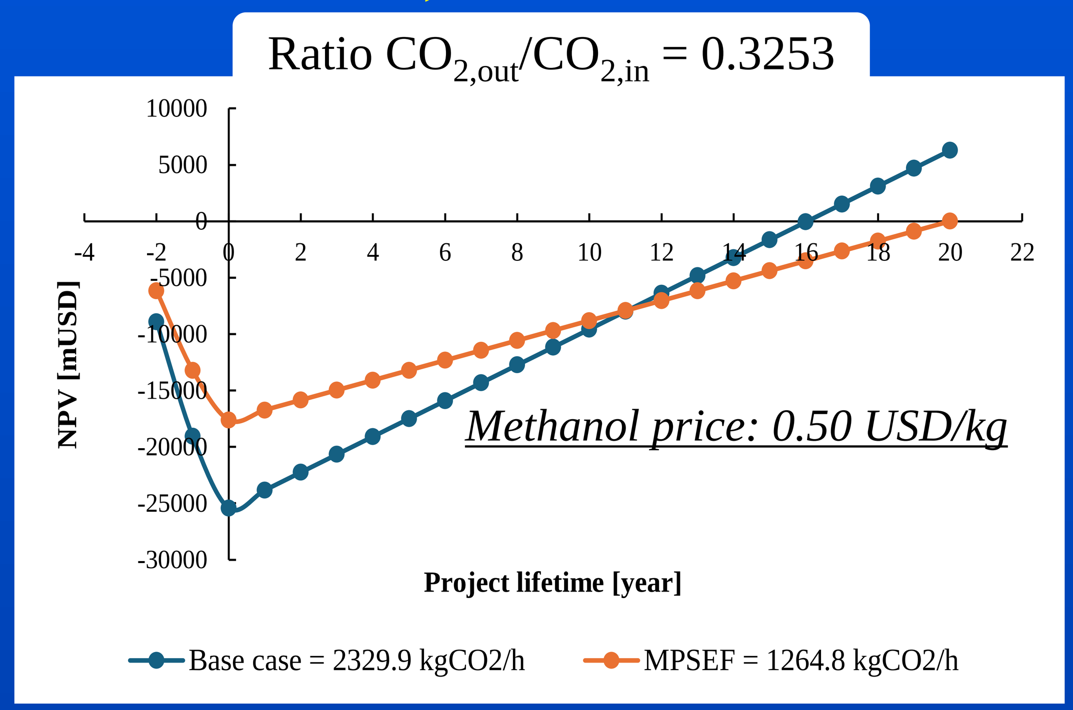
- Colombian context

- Tax rate: 35%
- Interest rate: 9.62%
- CEPCI: 803.20 (2024).
- Project lifetime: 20 years.

Results

The products yields obtained through CO_2 valorization scenarios are as follows: **methanol: 92.75%, ethanol: 78.26%**.

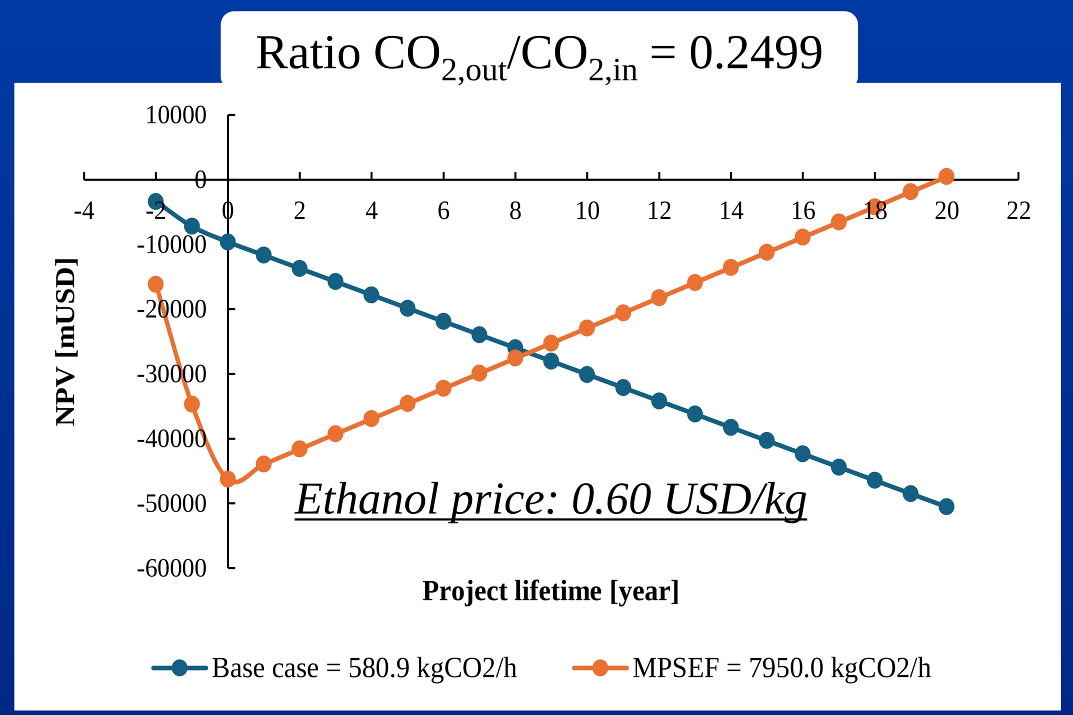
Ratio $CO_{2,out}/CO_{2,in}$ = 0.3253



CapEx [mUSD]=25.410	CapEx [mUSD]=17.612
OpEx [mUSD]=14.910	OpEx [mUSD]=12.602

Figure 4. Net Present Value (NPV) for CO_2 valorization through methanol production.

Ratio $CO_{2,out}/CO_{2,in}$ = 0.2499



CapEx [mUSD]=19.544	CapEx [mUSD]=22.354
OpEx [mUSD]=15.297	OpEx [mUSD]=19.846

Figure 5. Net Present Value (NPV) for CO_2 valorization through ethanol production.

Conclusions

The obtaining of methanol by catalytic hydrogenation of CO_2 is the most suitable option to be implemented in the Colombian context. The production of ethanol from CO_2 using cyanobacteria is a promising option, however, more research is still needed to improve yields towards ethanol production. Moreover, CO_2 valorization through C1 biorefineries schemes allows the mitigation of GHG emissions and contributes to an energetically viable production of high value-added products and energy vectors.

Future work

Future studies should analyze the effect of considering the carbon credits, tax benefits, and fines, regulated by the government, in a rigorous sensibility analysis for the economic assessment of the projects.

References

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[3] E. Y. Lee, et al. Frontiers in Microbiology, vol. 12, 2021.

Acknowledgements

This research work was funded within the framework of the research project “Aprovechamiento y valorización sostenible de residuos sólidos orgánicos y su posible aplicación en biorrefinerías y tecnologías de residuos a energía en el departamento de Sucre” code BPIN 2020000100189.