Evaluation of CO₂ Sources for the Microalgae Production

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Context

Enoil Bioenergies SA is planning to develop 1500 photobioreactors of 1m³ for the cultivation of Spirulina platensis for nutritional purpose. The algae farm will be located in Charrat (VS). The current source of CO₂ for the lab-scale algae farm is under the form of capsules.

Objectives

✓ Find an alternative to the current CO₂ source
✓ Integrate emissions of an other facility to perform CO₂ sequestration
✓ Identify a separation process to isolate CO₂ from the feed gas
✓ Design the separation process for the case study

Methodology

• Literature review: Study different CO₂ sources and separation processes
• Analysis of the case study: amount and purity of CO₂ requirement
• Evaluation of the CO₂ source fitting the case study
• Selection of the separation process fitting the requirements by comparing operational costs, energy needs and commercial availability
• Adaptation of the selected separation process

Results: Separation Process Comparison

CO₂ Requirements
- Composition: 99% CO₂, 1% CH₄
- Amount: 100 000 Nm³/year
- Recovery: 87.5%

CO₂ & CH₄
Membrane
MEA
PSA
Cryogenic distillation

Membrane:
Relatively simple mechanism acts like a sieve, that separates the feed-gas by using the different kinetic diameter of CO₂ (3.4 Å) and CH₄ (3.8 Å).

MEA (Monoethanolamine Absorption):
Chemical absorption on MEA: CO₂ dissolved in MEA solution due to exothermic reversible reaction between weak acid (CO₂) and a weak base (MEA).

Cryogenic distillation:
Energy intensive process, yet has high potential for the future. It utilizes the different boiling/sublimation points of the compounds of the feed-gas.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>PSA</th>
<th>Membrane</th>
<th>MEA</th>
<th>Cryogenic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purity</td>
<td>%</td>
<td>259</td>
<td>98</td>
<td>259</td>
<td>259</td>
</tr>
<tr>
<td>Recovery</td>
<td></td>
<td>98</td>
<td>90</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td>W/kg CO₂</td>
<td>0.2</td>
<td>0.34</td>
<td>1.1</td>
<td>0.5</td>
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<tr>
<td>Commercial availability</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>(for flue gas)</td>
<td>Low</td>
</tr>
</tbody>
</table>

High purity and recovery rate with high commercial availability → PSA is selected

Conclusion

• The biogas produced from WWTP in Martigny is selected as the CO₂ source because of its close location to the future algae farm and high CO₂ content.
• The gas separation utilizing PSA on Zeolite 5A enables to achieve the CO₂ requirement.

Recommendations

➢ The gas cleaning step for removing impurities such as H₂S, NH₃, siloxane, needs to be further developed before implementation

➢ The comprehensive cost analysis should take place between three parties (Enoil, separation technology provider and CO₂ source industry) to meet the specific needs of the algae farm in Charrat

➢ The production of waste should be considered for a better management and ensure the future algae farm to be sustainable

➢ Feeding the algae with bicarbonate can be considered especially if flue gas is considered in the future

Final Design: PSA (Pressure Swing Adsorption)

PSA mainly consists of four phases: (1) Pressurization (2) feed (3) blow-down, and (4) Purge. The performance of PSA relies on the capacity of adsorbent materials.

To ensure high purity and recovery rate, a double PSA units systems are evaluated. Each unit consists of 4 columns.

References

Bauer et al. (2013): “Biofuel-upgrading through rich-very rich, comp. and perspectives for the future.” Biofuels, 4:634–651
Hulaa et al. (2008): “Comparing different biogas upgrading techniques.” Endomewm University of Technology

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