ccsp
Carbon Capture and Storage Program

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CO_2 from industrial off-gases for algae cultivation

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Objective

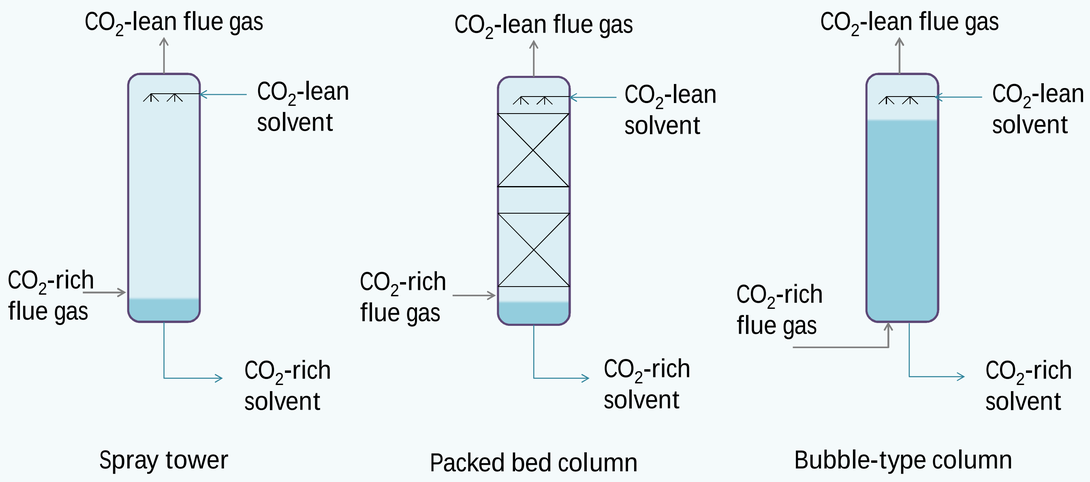
- In CCSP, new methods for sustainable industrial utilization of CO_2 are studied, the main focus being on CO_2 uptake by microalgae
- The ultimate objective is to create technological readiness for a pilot plant utilizing microalgae for CO_2 capture and biogas/-fuel production

Work done so far

- Review of technical solutions for capturing CO_2 from CO_2-containing off-gases for feeding an algal cultivation
- Experimental research on cultivation of algae using
  1. vent gases from a sour gas processing plant
  2. flue gases from a coal-fired combined heat and power (CHP) plant

Technical solutions for capturing CO_2

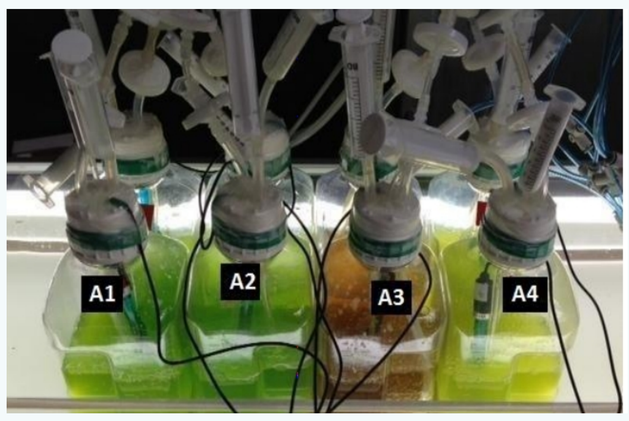
- The most promising methods for CO_2 capture seem to be those that absorb CO_2 directly into the cultivation media by using separate *bubbling* carbonation columns
  - Both for open ponds and closed photobioreactors
  - Lower energy requirements than direct gas injection
  - Enables the remainder of the flue gas to be led out through the existing flue gas stack
- The low capacity of water to dissolve CO_2 can be improved by addition of alkaline salts



Cultivation using CHP plant flue gas

- Flue gas from Suomenoja CHP plant in Finland was used
- Three microalgal species and one cyanobacterium (bottle A4 in the figure below) were cultivated in the flue gas
- All *microalgal* species grew similarly in flue gas and pure CO_2
- *Cyanobacteria* are more sensitive to NOx and Sox
  → cyanobacteria growth was inhibited in flue gas

Compound	Flue gas
Carbon dioxide (CO_2)	12 %
Oxygen (O_2)	5.7 %
Water vapour (H_2O)	9.4 %
Nitrogen (N_2)	73 %
Nitrogen oxides (NOx)	200 ppm
Sulphur oxides (SOx)	210 ppm



Cultivation using vent gas

- Seven microalgae and one mixture of selected microalgae were cultivated with CO_2 by employing a 20 L photobioreactor (PBR)
- Vent gas from Hazira sour gas processing plant in India was used for further testing:

Compound	Vent gas
Carbon dioxide (CO_2)	28-56 %
Oxygen (O_2)	9-11 %
Water vapour (H_2O)	9-16 %
Nitrogen (N_2)	39-41 %
Hydrocarbons	<1.0 %
Hydrogen sulfide (H_2S)	< 30 ppm

- Both test subjects – the mixture of selected algae and *Chlorella sp* – grew well in the vent gas
  - No indications of any toxic influence of the vent gas on the selected algae was found
- A microalgae yield of 18 g/m^2/day was achieved using *Chlorella sp*, which on anaerobic digestion yielded about 0.4 L CH_4/g volatile solids fed

Next steps

- Techno-economic evaluations, further experimental work, and a conceptual design for a pilot

Carbon Capture and Storage Program (CCSP)

- Carbon Capture and Storage Program (CCSP) is a Finnish R&D program, funded by Tekes & program partners
- Collaboration with India through ONGC
- 17 industry partners, 9 research partners
- Time span: 1.1.2011 – 31.10.2016
- Volume: 15 M€

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In this work, technical solutions for capturing CO_2 from CO_2-containing off-gases from industry for feeding an algal cultivation were qualitatively evaluated. Also, cultivation of algae using both vent gases from a sour gas processing plant and flue gases from a coal-fired combined heat and power (CHP) plant was studied.

The most promising methods for CO_2 capture seem to be those that absorb CO_2 directly into the cultivation media by using separate bubbling carbonation columns, both for open ponds and closed photobioreactors. This lowers the energy requirements in comparison to flue gas injection and also enables the remainder of the flue gas to be led out through the existing flue gas stack. The low capacity of water to dissolve CO_2 can be improved by addition of alkaline salts.

The growth of two green algae, one diatom, and one cyanobacterium was examined in a laboratory-scale, batch-mode comparative cultivation experiment, using both pure CO_2 and flue gas from a coal-fired CHP plant. No significant statistical differences in the growth were observed between the experiments except for the cyanobacterium, which had a decreased growth during flue gas cultivation.

Microalgae suitable for cultivation using vent gases from a sour gas processing plant were screened by employing a 20 L photobioreactor. Based on these experiments, a certain mixture of microalgae exhibited rapid growth and better tolerance towards in terms of time taken to reach pH 7. A small-scale CO_2 capture and cultivation pilot was set up using a 0.3 m^3 CO_2 absorption column for absorbing CO_2 from vent gas in connection to a 0.2 m^3 raceway pond. The produced algae was harvested and sent for anaerobic digestion studies. The experiments were successful, with a microalgae yield of 18 g/m^2/day achieved, which on anaerobic digestion yielded about 0.4 m^3 CH_4/kg volatile solids fed.