CO_2 CAPTURE FROM AIR TO PROVIDE A SUSTAINABLE CARBON SOURCE FOR MICROALGAE CULTIVATION

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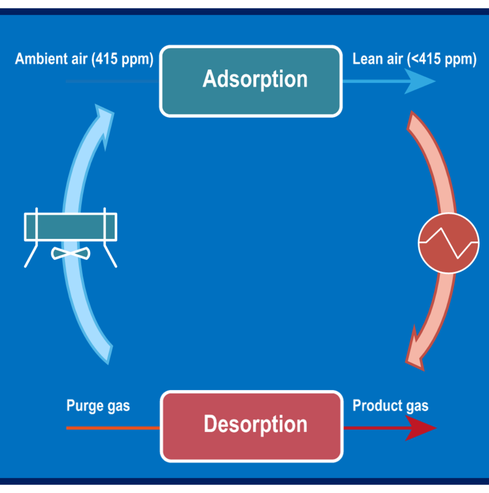
Direct Air Capture

Direct air capture (DAC) is the extraction of CO_2 from the atmosphere. It is the ultimate form of CO_2 recycling when combined with CO_2 utilization processes, for example microalgae cultivation. In current cultivation processes, CO_2 sources are usually fossil-based. DAC therefore offers a sustainable alternative.



- Chemical adsorption using amine-based solid sorbents
  - Adsorption at ambient conditions (no pre-treatment of air)
  - Desorption at increased temperature and reduced pressure
- Production of concentrated CO_2
  - Desorption with a condensable purge gas (steam)

Goal: Demonstration of this DAC technology at algae cultivation facilities in Belgium and Germany

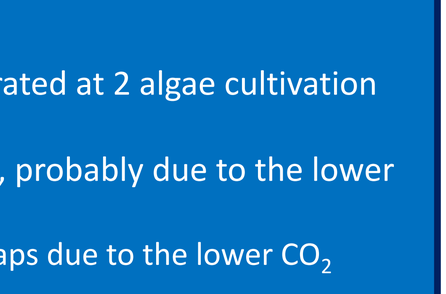
Direct air capture unit in numbers

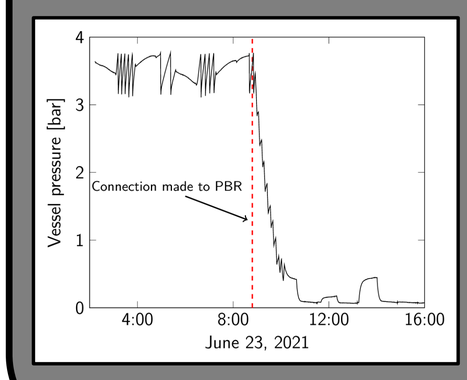
Parameter	Value	Unit
# of reactors	4	
Reactor diameter	40	cm
Reactor thickness	2.5	cm
Demo unit size	120x80x200	cm
Air flow	4500	m^3/day

Reactor	1	2	3	4	Total
Productivity (kg_{CO2}/day)	0.30	0.33	0.27	0.27	1.17
Productivity ($kg_{CO2}/kg_{sorbent}$/day)	0.21	0.23	0.19	0.21	0.21
Working capacity ($mol_{CO2}/kg_{sorbent}$)	0.66	0.74	0.61	0.66	0.67
Product purity (vol.%)	-	-	-	-	29
Energy duty (MJ/kg_{CO2})	-	-	-	-	45

Demonstration at FZJ (Germany)

- 300 liter total volume
- Bags with continuous air flow
- pH based CO_2 supply
- DAC capture demonstration combined with MAF demonstration
  - Not connected to same PBR
  - Control PBR for comparison
- Demonstration
  - Consortium dominated by Chlorella
  - Ongoing since 21 June 2021



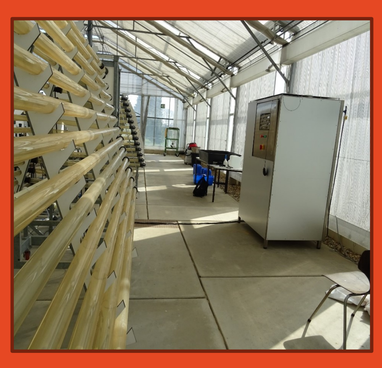


Preliminary conclusions

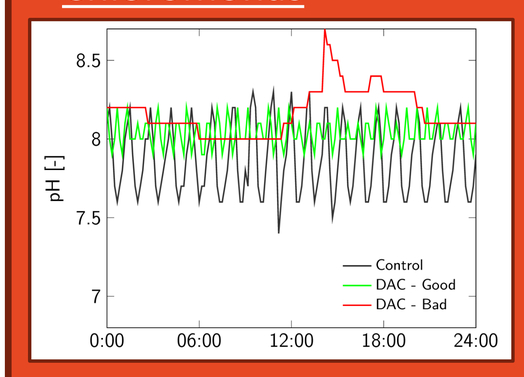
- Stable operation, although one reactor does not reach sufficient vacuum
- High temperature in greenhouse can cause problems for cooling
- CO_2 requirements exceeds production
  - Fast consumption of CO_2 (see graph)
  - Higher growth rate?, lower CO_2 purity?, lower CO_2 efficiency of PBR?

Demonstration at Sunbuilt (Belgium)

- 300 liter photobioreactor
- Two-phase tubular PBR
- pH based CO_2 supply
- One control PBR for comparison
- Demonstrations
  Chloromonas: 7 – 21 April 2021
  Nannochloropsis: 26 May – 3 June 2021



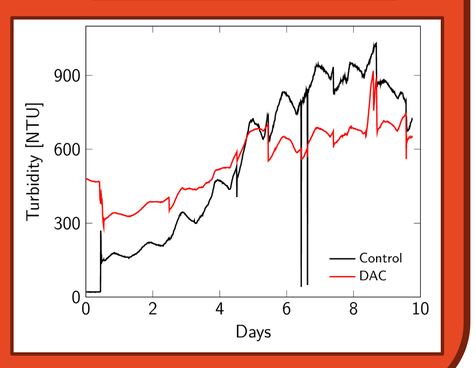
Chloromonas



- pH control is comparable to control reactor (green curve in graph)
- Growth rate not comparable
  - Start-up issues with DAC unit
- pH control not sufficient after malfunction of vacuum pump
  - CO_2 concentration decreased significantly (red curve in graph)

Nannochloropsis

- pH control is similar to Chloromonas test
- Algae have same appearance
  - By visual inspection and under microscope
- No contaminations in cultivation medium in both PBRs
- Some differences observed in turbidity
  - Increase is much slower for DAC reactor
  - DAC reactor reacts less for sudden temperature changes and during the night
  - Possibly due to lower CO_2 concentration



Conclusions

Proof of concept

- DAC for microalgae cultivation was demonstrated at 2 algae cultivation facilities for 3 different algae species
- pH regulation was comparable (if not better), probably due to the lower CO_2 concentration (29 vol.% vs 100 vol.%)
- Growth rate seems lower for CO_2 from air, perhaps due to the lower CO_2 concentration

Improvements

- Robustness of DAC capture unit is not yet sufficient
  - Loss of vacuum during desorption → Drop in CO_2 concentration and risk of sorbent degradation
- CO_2 concentration is lower than aimed for due to small leakages
- High temperatures can cause problems to the process
  - Cooling is facilitated by an air cooler, which may not be sufficient at > 40°C
  - Heat produced by equipment causes temperature to rise inside reactor unit

IDEA - Implementation and development of economic viable algae-based value chains (NWE639)

Duration: 9/2017 – 10/2021, capitalisation till 12/2023

Website: www.nweurope.eu/IDEA

Lead partner: VITO, Belgium

Full IDEA partners: JÜLICH Forschungszentrum, Innovatiesteunpunt, CentraleSupélec, FEED DESIGN LAB, THOMAS MORE, Cegasc, UNIVERSITY OF TWENTE.