Algae growth on CO_2 from (combusted) biogas

Final IDEA+ event, September 2023

Wim Brilman – University of Twente

Kris Heirbaut – Heirbaut Algriculture

Capture and separation of CO_2/CH_4 gases from biogas

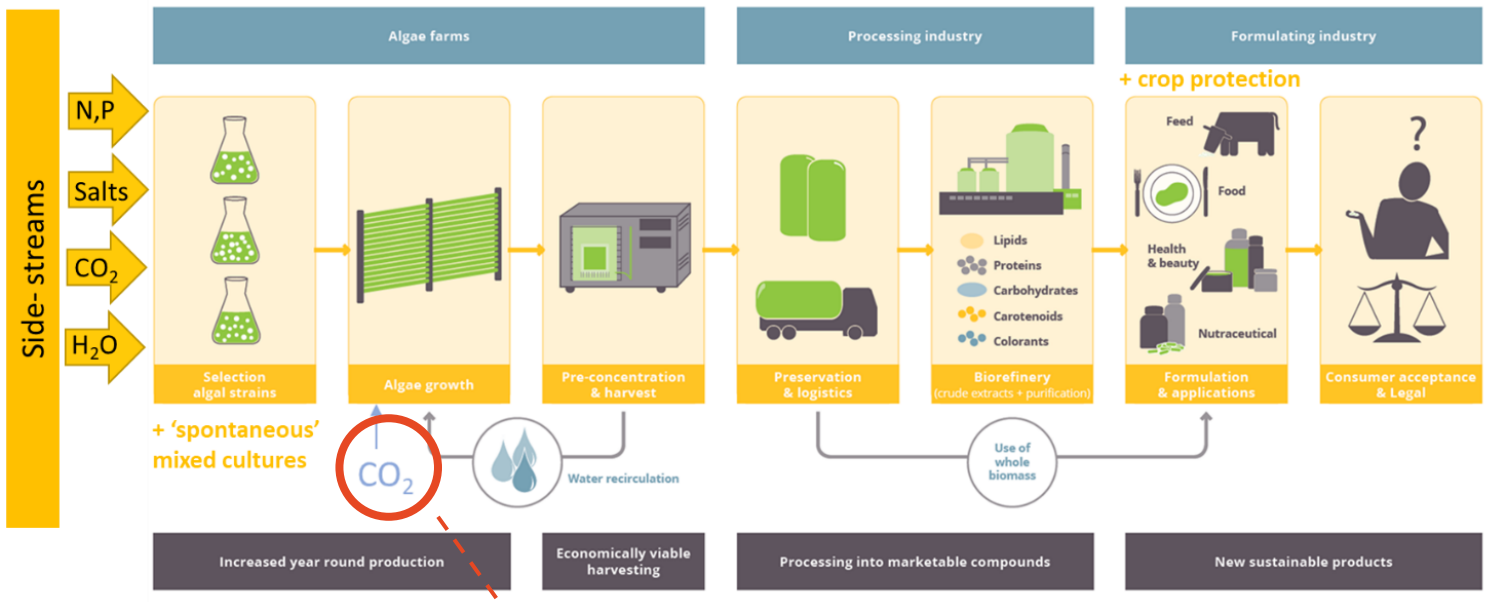
Final IDEA+ event, September 2023

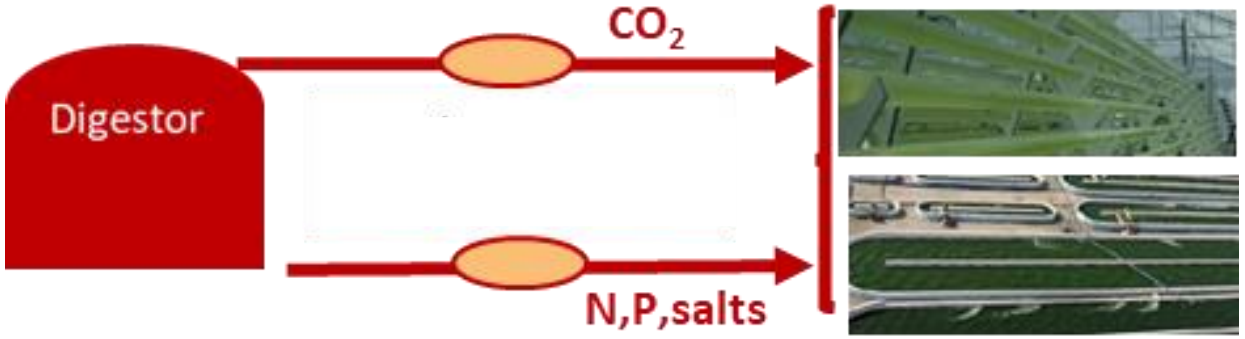
Wim Brilman

co-workers: Abhinav Srinivas
Michel Schellevis
Diana Siretanu
Niels Mendel

UNIVERSITY OF TWENTE.

CO_2 from biogas for microalgae



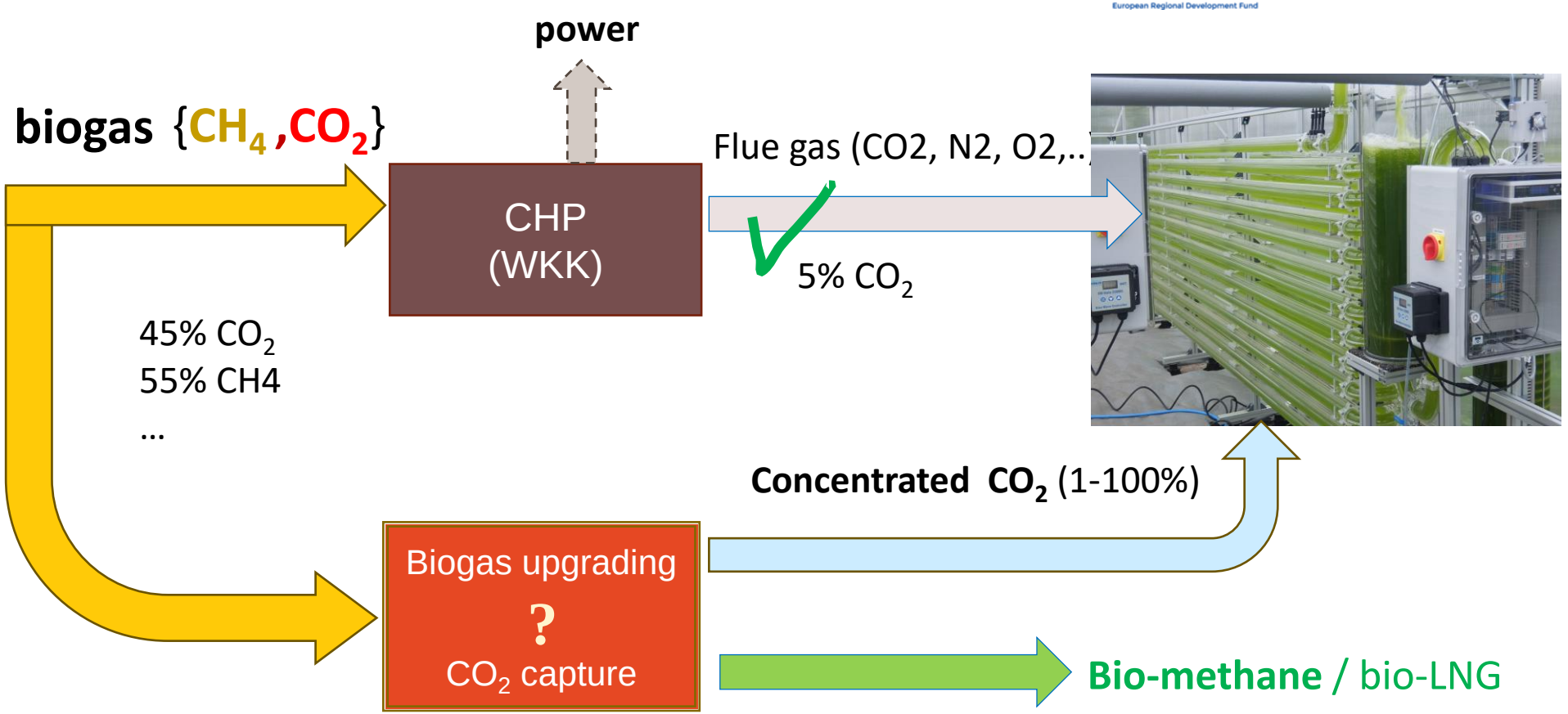


IDEA-PLUS project:

Development of economic viable value chains based on micro-algae cultivation in NW-EUROPE

Nutrients from digestor (N,P, minerals and CO_2) :
ca. 25% savings in microalgae cultivation costs
+
Full utilization of biogas by
Upgrading biogas to bio-methane or bio-LNG

Options for CO_2 from biogas for microalgae

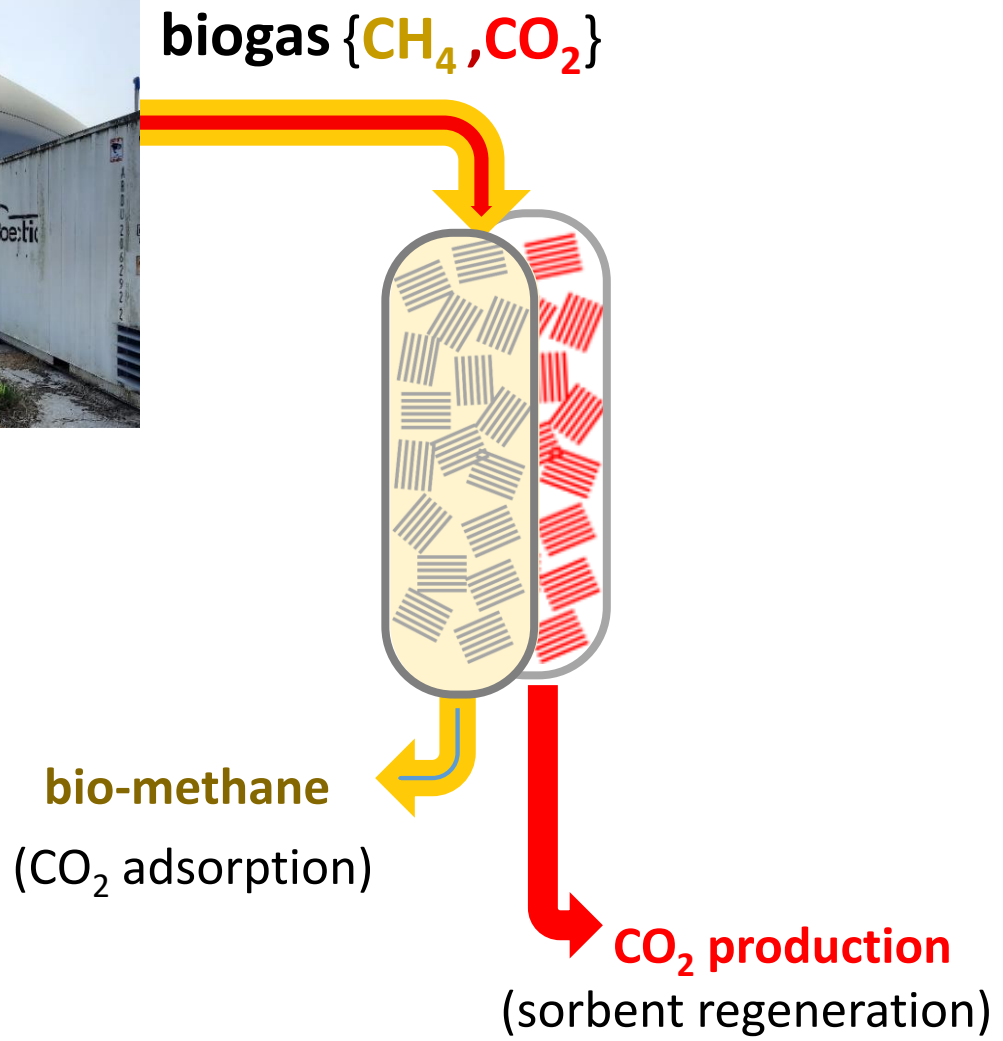


- Existing upgrading techniques (membranes, aq.amine scrubbers) are not economic at small (farm) scale
- Separating CO_2 and CH_4 (methane): option to feed methane to gas grid.

Two technologies

Requirements:

- Robust technology
- high methane recovery (>99.5%)
- ‘low’ temperature and pressure
- min. energy requirement

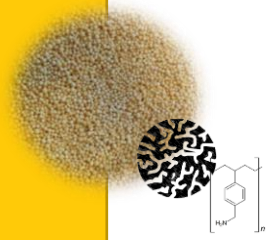


Two concepts developed :

Option 1: Fixed bed of polymer IER (ion exchange resin) particles
(see IDEA project - DAC pilot plant – CO2 from air)
(sorbent regeneration using air purge at 50 °C)

Option 2: Fixed bed of modified clay particles
(vacuum-swing adsorption, 20 °C)

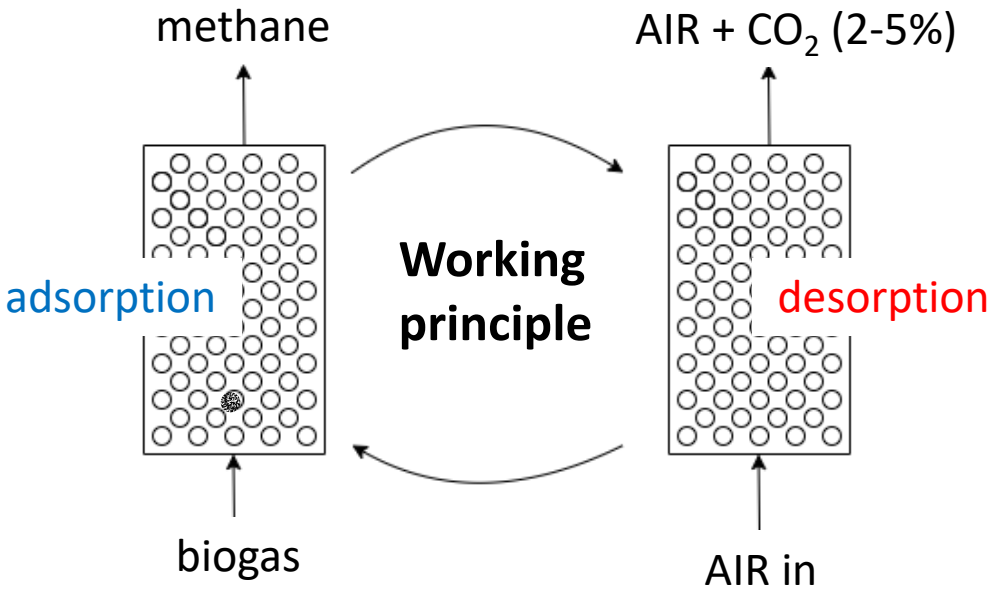
Option 1: IER sorbent and regeneration with air purge

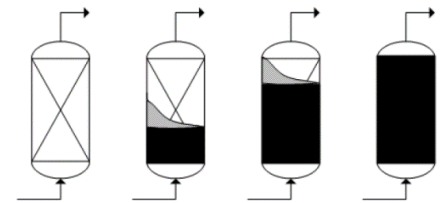


CO_2 adsorption capacity:
during adsorption from biogas: **2.5** mol/kg (at 50°C)
during rinsing with air: 0.5 – **1.0** mol/kg (dep. on RH)

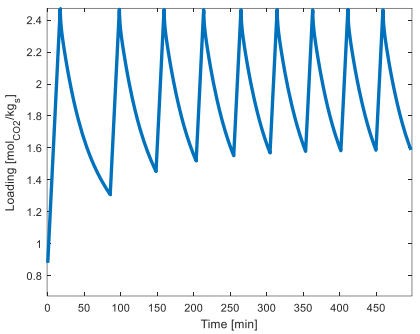
} Difference in capacity = basis for CO_2 separation

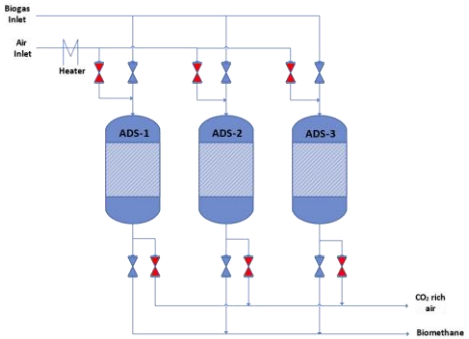
CH_4 adsorption capacity ≈ 0





Experimental => adsorber model => process design





Strong adsorption => strong temperature effects
Cyclic operation => keep heat of adsorption inside bed
to avoid time/energy for heat up/cool down
(=> good insulation needed!)

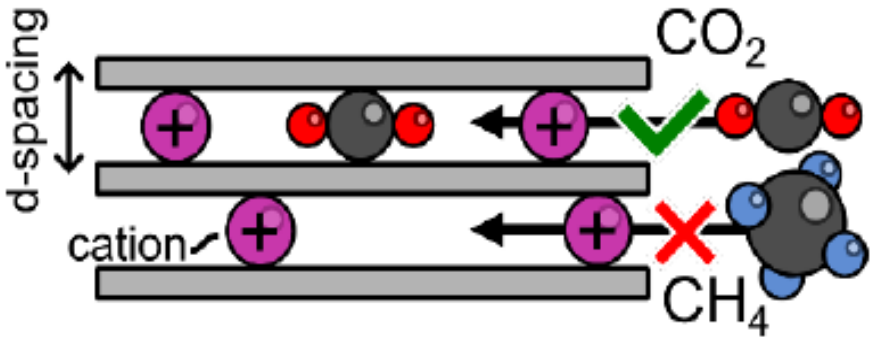
Methane purity and -recovery > 98% , CO_2 product purity = 2-5%

Steady state cyclic operation is demonstrated
Temperature excursions can be limited by feed gas preheating

Option 2: modified clay sorbent

Working principle:

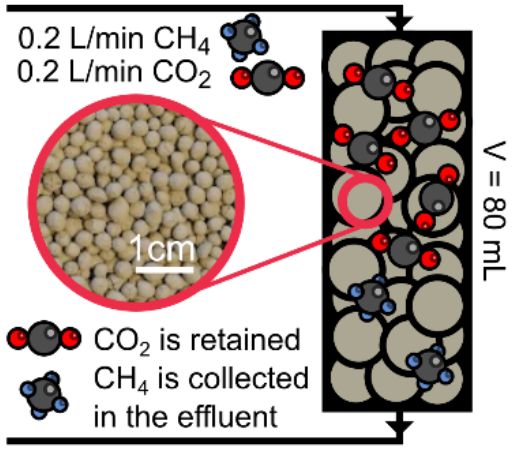
- CO_2 storage in the clay 'interlayers'
- size exclusion: CH_4/CO_2 selectivity (~25-40)



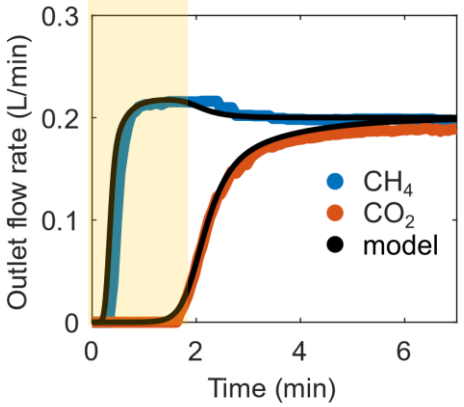
Advantages:

- Low heat of adsorption (low energy use)
- Fast adsorption / desorption
- cheap raw materials for sorbent preparation

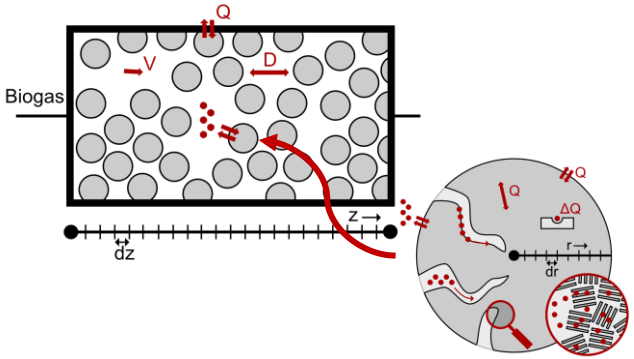
Proof of principle – lab study + reactor model



CH_4 product



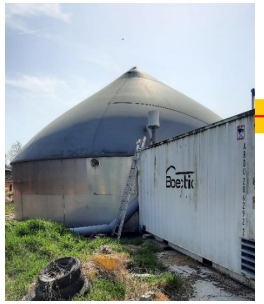
Adsorption model:



Model is used to design farm-scale unit

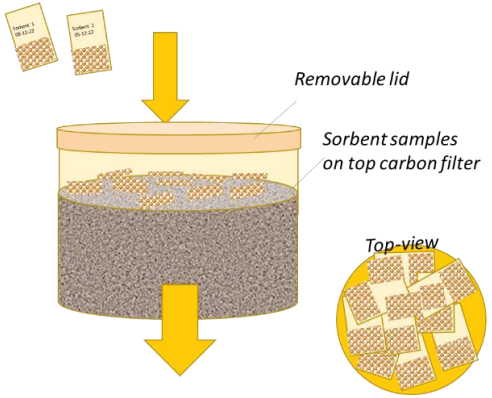
Demonstration at farm scale is still needed

De-risking: Sorbent stability in real biogas ?

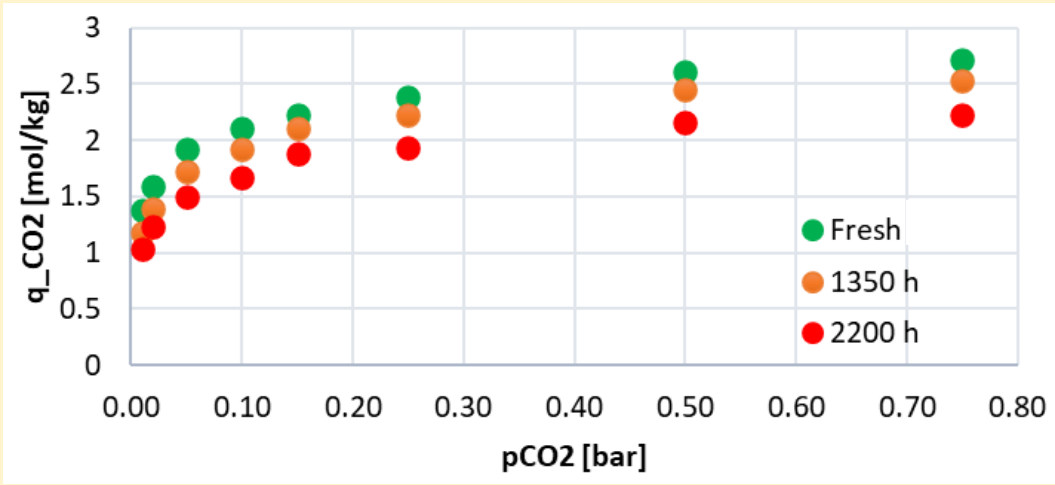


biogas {CH_4 ,CO_2}

Both sorbents exposed to real biogas at Heirbaut farm



Other IER sorbent stability findings:
Same sorbent was used within IDEA for DAC, and was in contact with few% O_2 at ca. 110 °C
Graph below shows degradation during IDEA-DAC campaign



Sorbents (both IER and clay sorbent) did not show any degradation during experimental campaign (discontinuous exposure, stretching over 9 months)

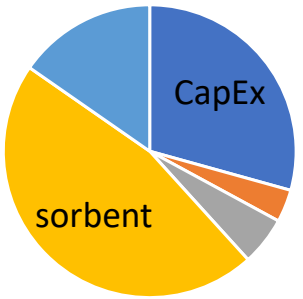
Comparison and Conclusions

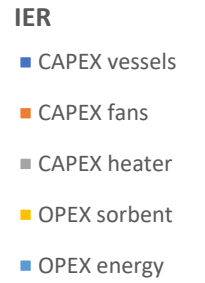
- Two robust, fixed bed technologies have designed and tested with synthetic biogas
  - (1) IER based process with air purge for regeneration
  - (2) Clay based process with vacuum swing
- Sorbents were shown to be stable, when using real biogas

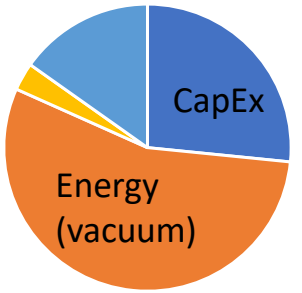
Process design results*

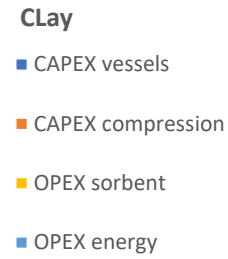
	IER	**Clay**	
Methane purity	98%	93%	(both sufficient for NL gas grid)
Methane recovery	99.7 %	99.6 %	
CO2 purity	2.4 %	99.3 %	
Power consumption	0.10	0.13	kWh_{el}/Nm^3
Process intensity	47	25	$(Nm^3/h)_{biogas}$ per m^3 sorbent

* Results can be tuned / improved further by process design changes









Both processes look promising. Concept proven and conceptual design is prepared.
Next steps required: outdoor piloting and detailed evaluation of business case

Algae growth on recycled CO_2 from biogas at larger scale

Final IDEA+ event, September 2023

Kris Heirbaut – Heirbaut Algriculture

CHP

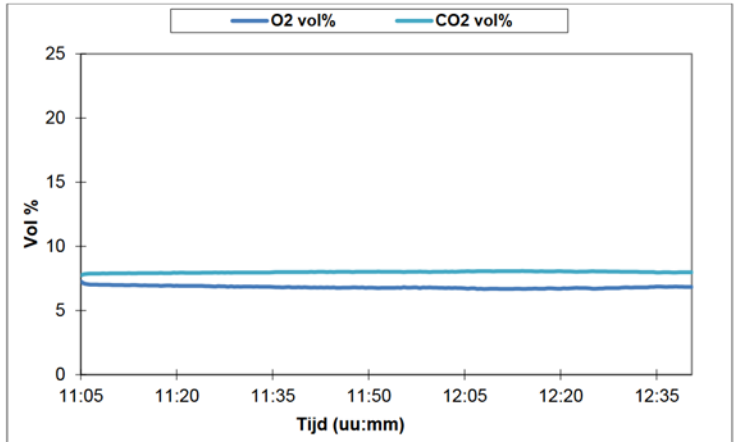
H2O to wash flue gases: SO2, dust, volatile organic compounds, odeur,….

3.1 WKK

Parameter	Eenheid	Tijdstip	Gemeten waarde WKK				
Datum			3/11/2021				
Atmosferische druk	*Pa*		100100				
Absolute druk schoorsteen	*Pa*		99928				
Gemiddelde temperatuur	*°C*	9:10 - 9:15	81				
Gemiddelde snelheid S-pitot	$m.s^{-1}$	9:10 - 9:15	22,6				
Debiet (droge gassen)	$Nm^3.h^{-1}$		105				
Debiet (natte gassen)	$Nm^3.h^{-1}$		122				
Waterdampgehalte (natte gassen) = berekend	*vol %*		13,7				
Basissamenstelling droog rookgas			**Concentratie Vol %**		**Massadebiet g/h**		
O_2		11:05 - 12:41	6,8				
CO_2		11:05 - 12:41	8,0		16483		
Gasvormige polluenten			**Concentratie mg/Nm³**	**Concentratie omgerekend naar 15 vol% O2 mg/Nm³**	**Massadebiet g/h**	**Staalnummer(s)**	**Adsorptie-middel**
CO		11:05 - 12:41	850	358	89		
NO_x		11:05 - 12:41	258	109	27		
SO_2		11:05 - 12:41	40	17	4,2		
TOC		11:10 - 12:40	1348	570	142		
Methaan		11:10 - 12:40	1289	545	135		

BIJLAGE I: Grafisch verloop van de continu gemeten parameters

WKK



Contact time: 3 seconds


DURAN
65,00
1459938

Chlorella Day 1: OD 1,00 ; pH 7,5

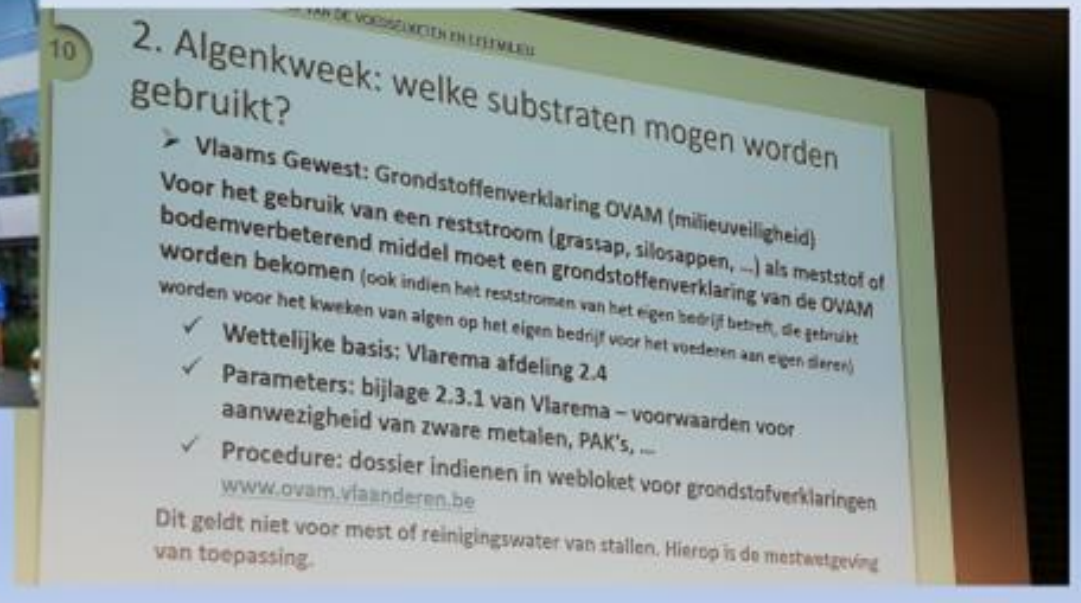
- <u>OD 6 days after fertilization:</u>
- Filtered digestate – 1,70
- Filtered grass juice – 1,65
- Organic CellHiBio – 1,80
- CellHiBio + grass juice – 1,90

- <u>pH 6 days after fertilization</u>
- pH 7,1
- pH 7,0
- pH 7,7
- pH 7,3

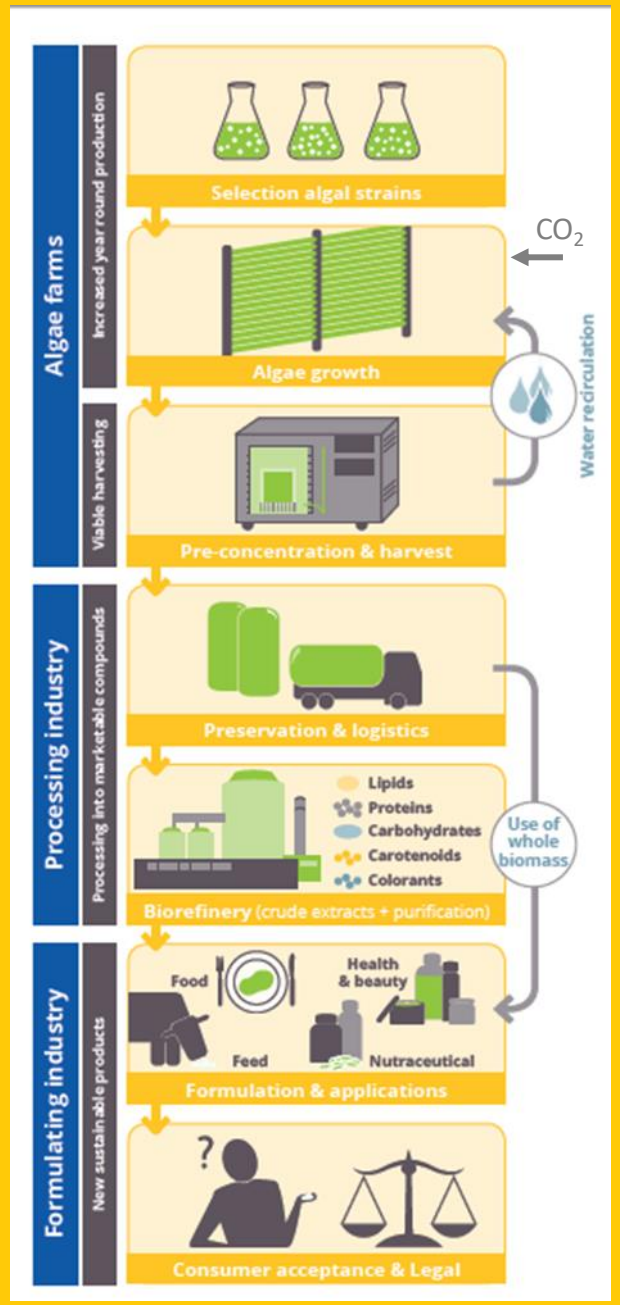
Grondstoffenverklaring

SAMEN MAKEN WE MORGEN MOOIER

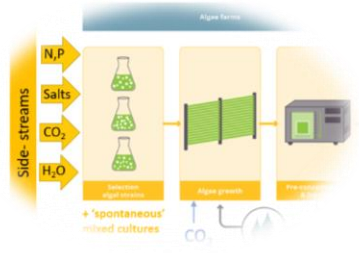
OVAM



Interreg
North-West Europe
IDEA
European Regional Development Fund



Acknowledgements



This research was funded by NORTH-WEST EUROPE INTERREG, grant number NWE 639 as part of the IDEA project (Implementation and development of economic viable algae-based value chains in North-West Europe).

Website: www.nweurope.eu/idea

Full partners: