Microalgae-based biogas upgrading: a sustainability driven technology

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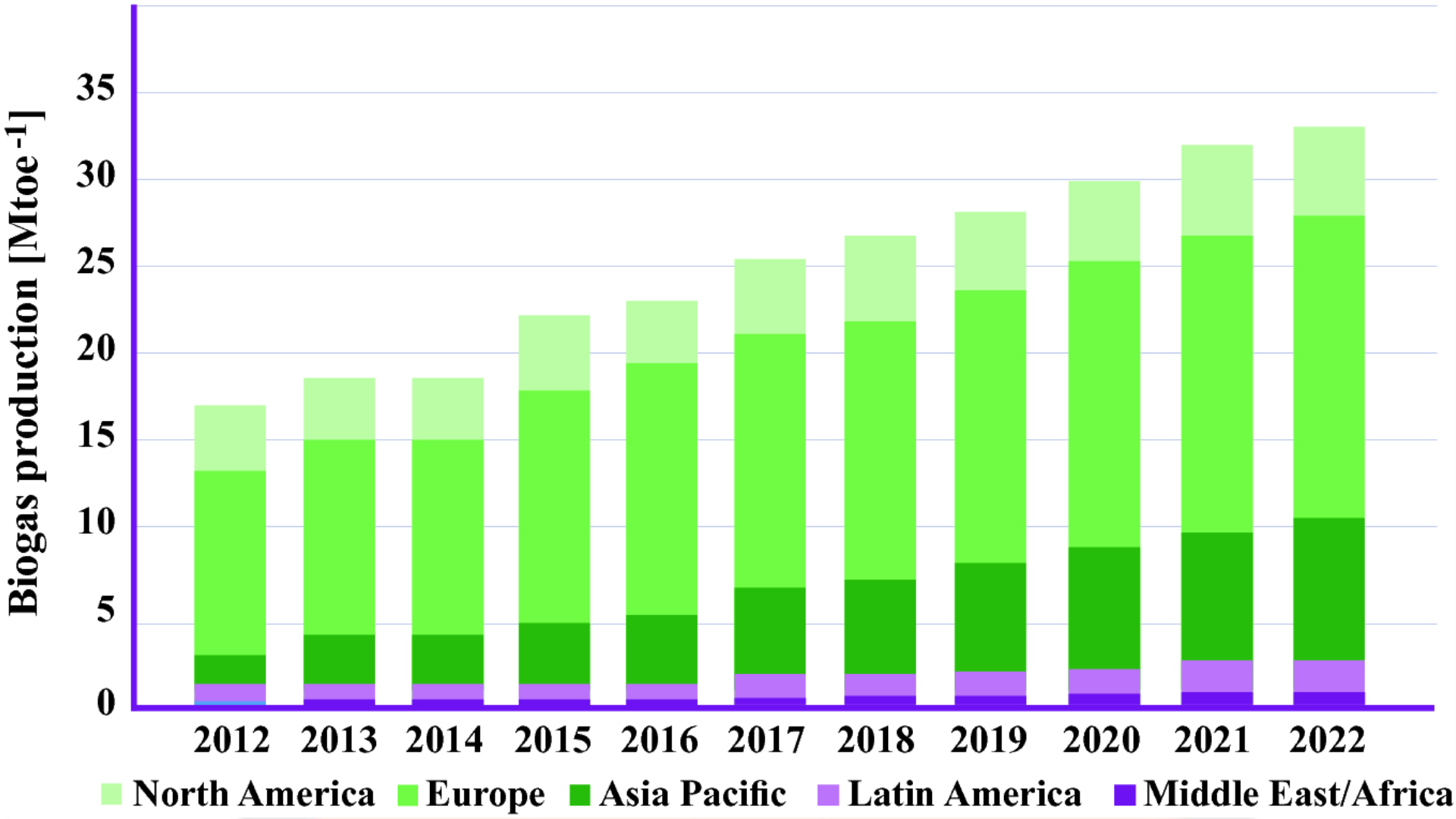
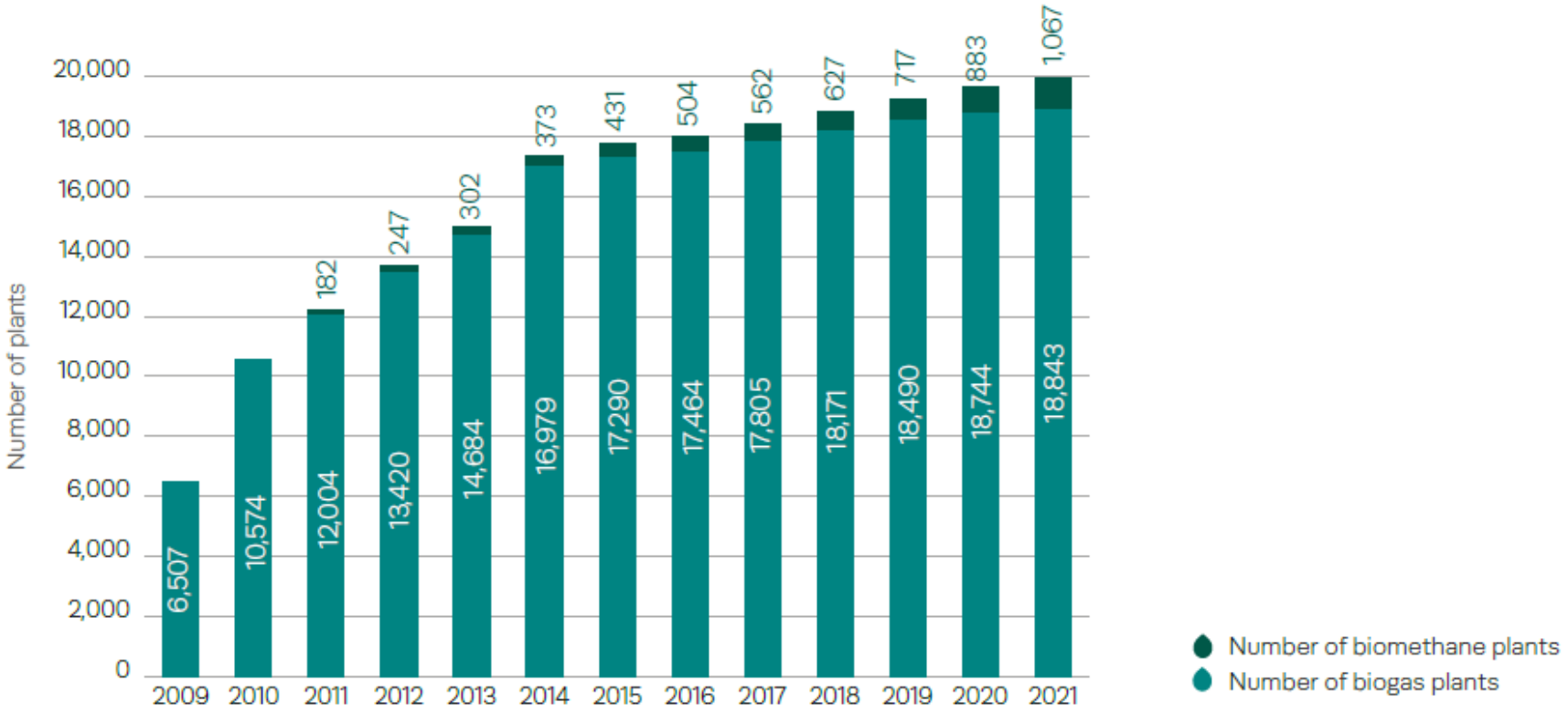
The biogas market



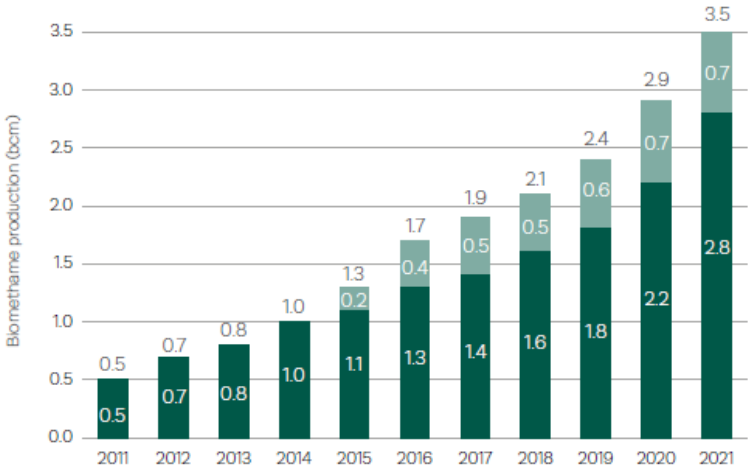
The biogas market



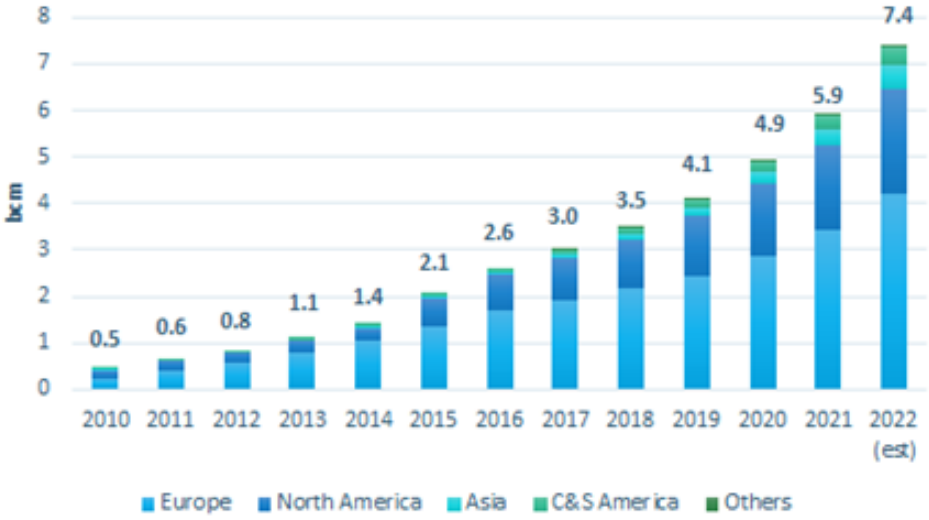
(EBA, 2021)

The biomethane market

Europe



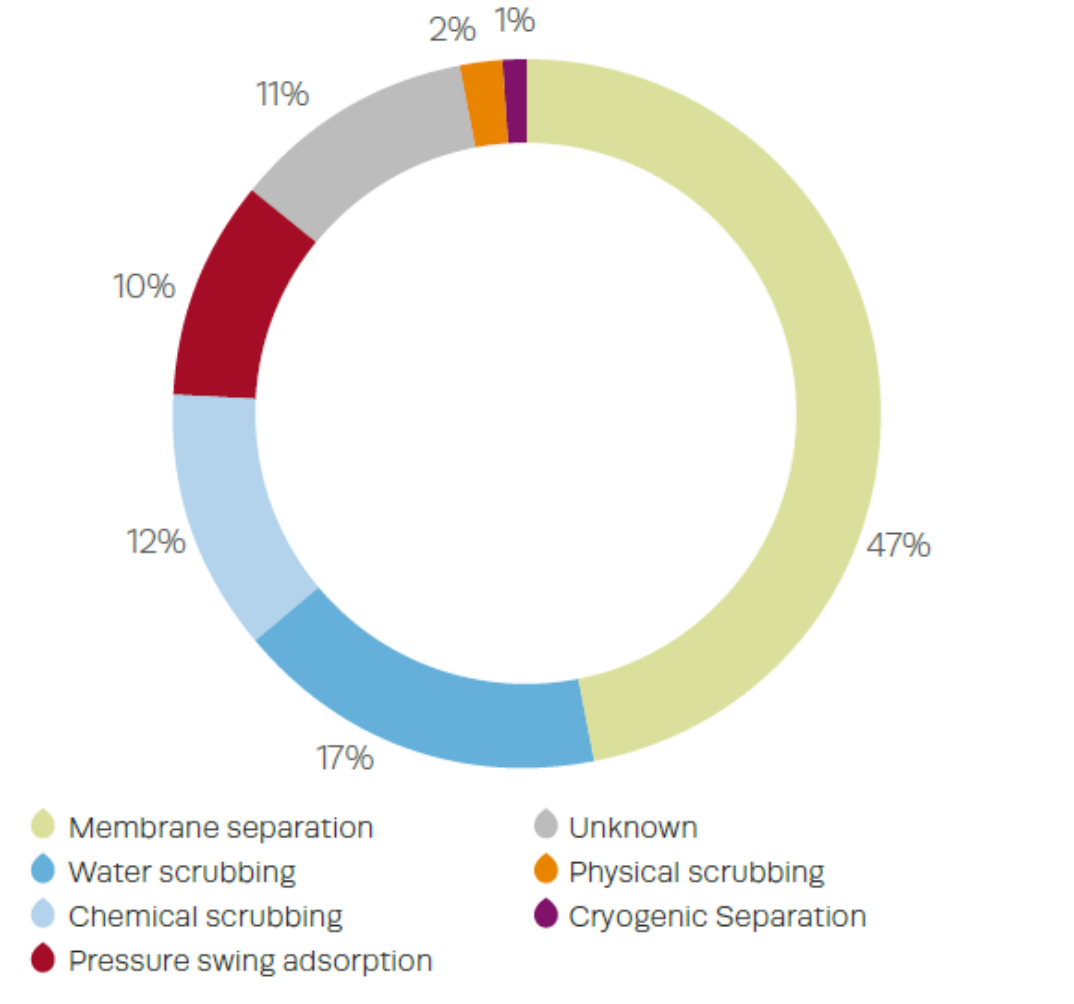
World



(EBA, 2022)

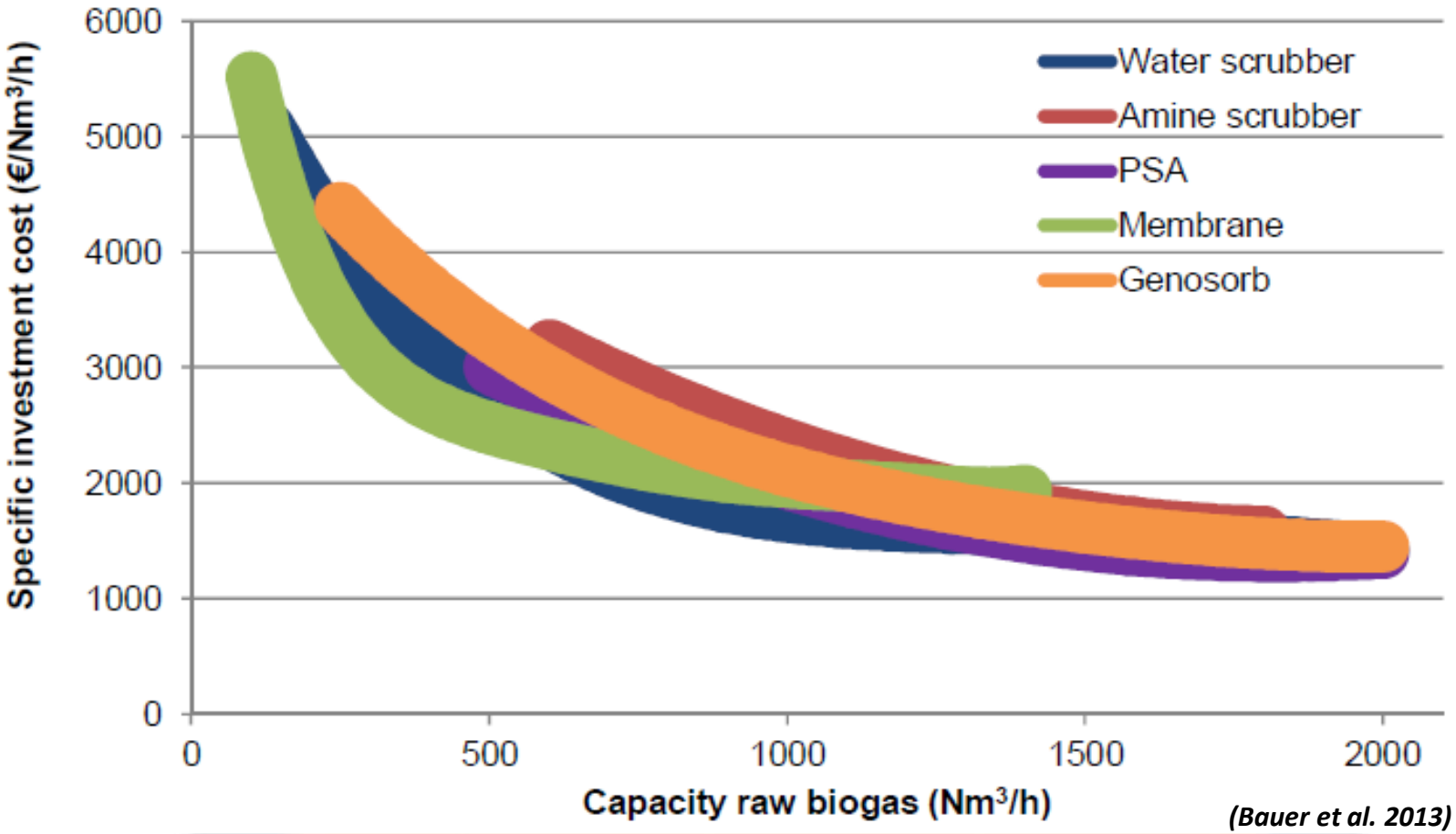
The biogas upgrading market

Today….



(EBA 2022)

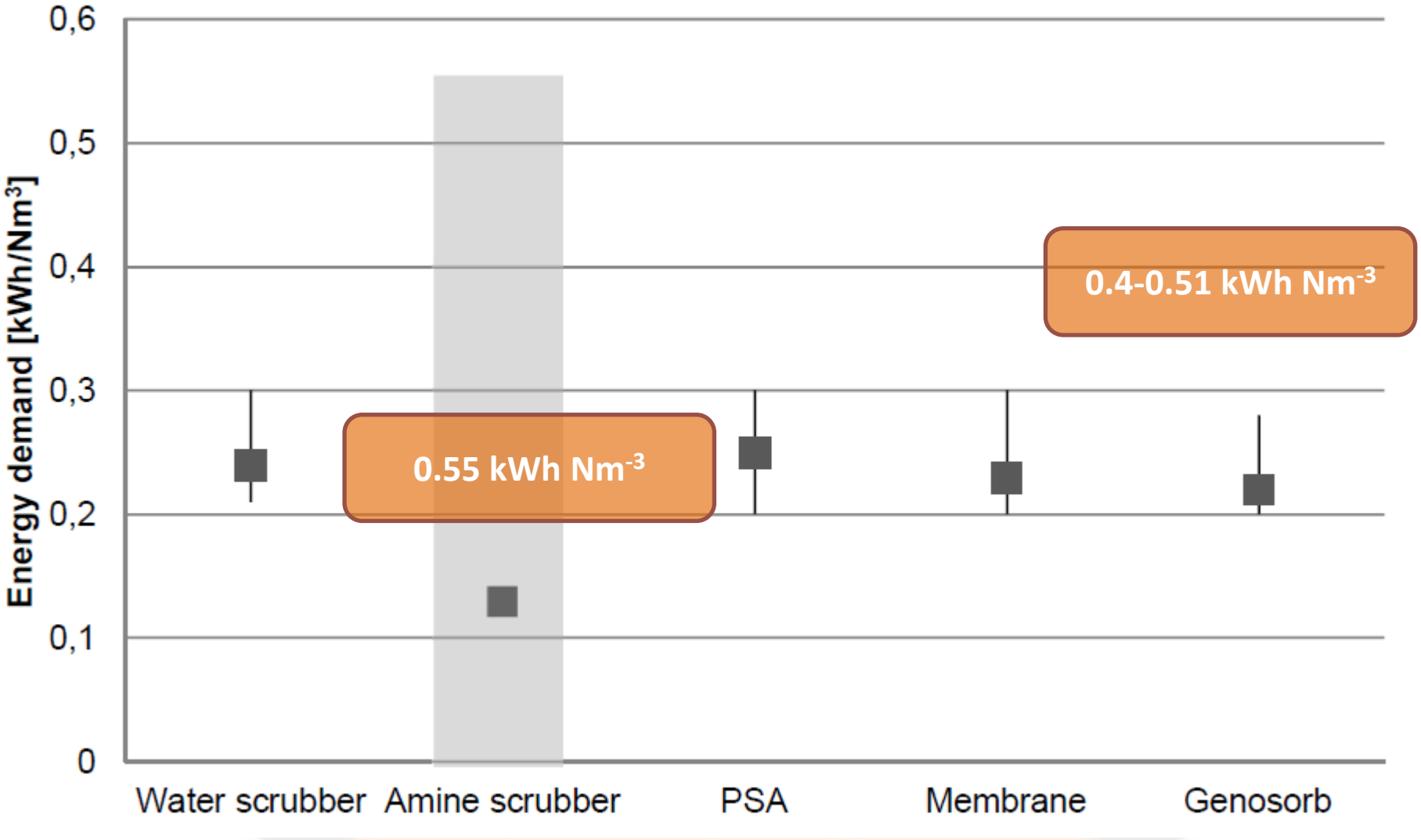
Physical/Chemical CO_2 removal Technologies



(Bauer et al. 2013)

Physical/Chemical CO_2 removal Technologies

Energy demand: 3-12 % energy content of Biogas

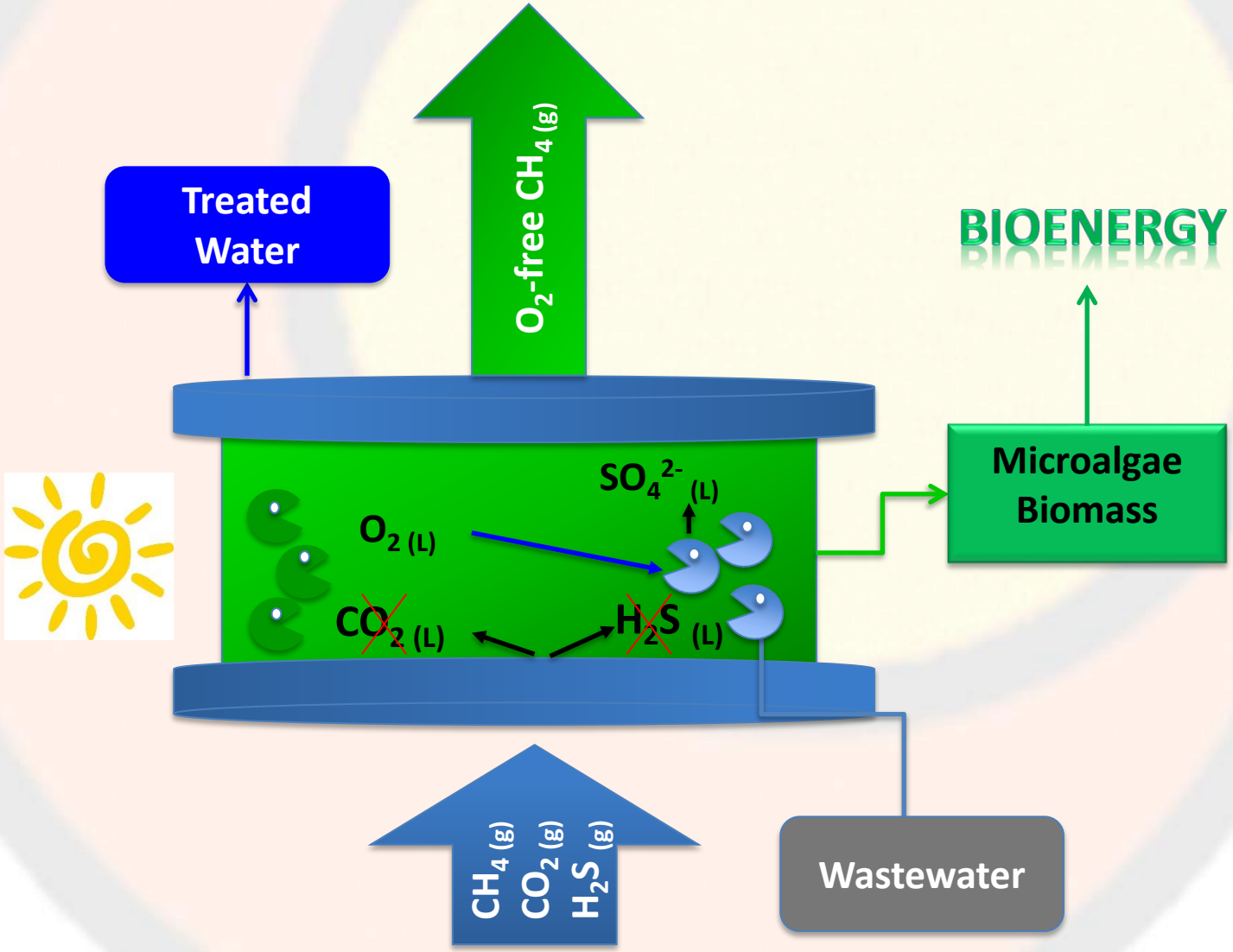


(Bauer et al. 2013)

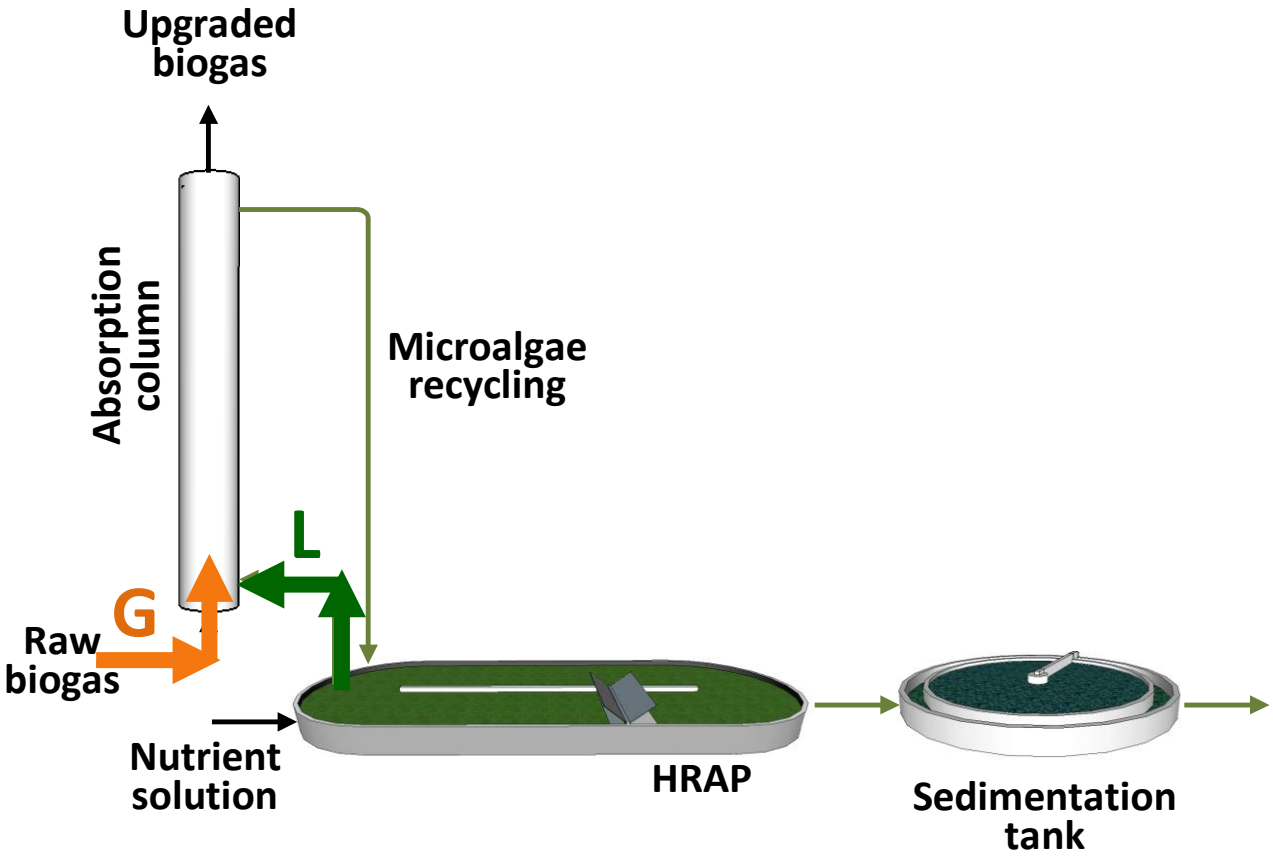
Technology Niche

Need to develop innovative low-cost & environmentally friendly technologies for a sustainable Biogas upgrading at small-medium scale

Photosynthetic Biogas Upgrading



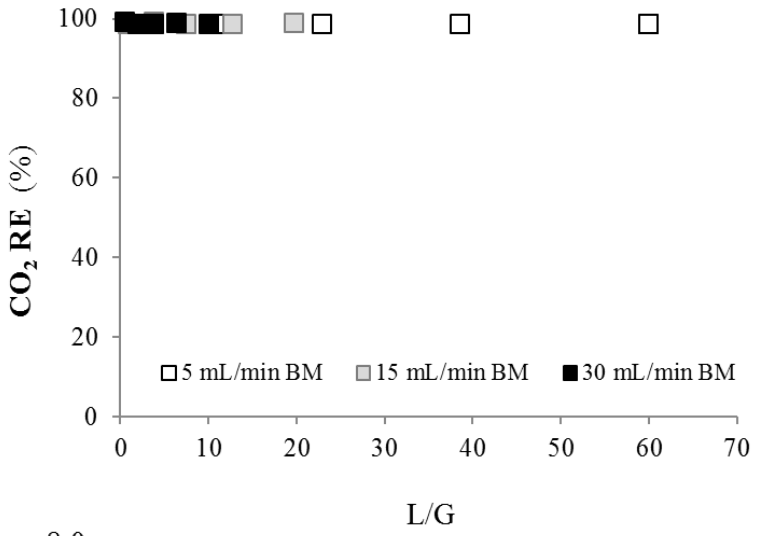
Photosynthetic Upgrading Optimization

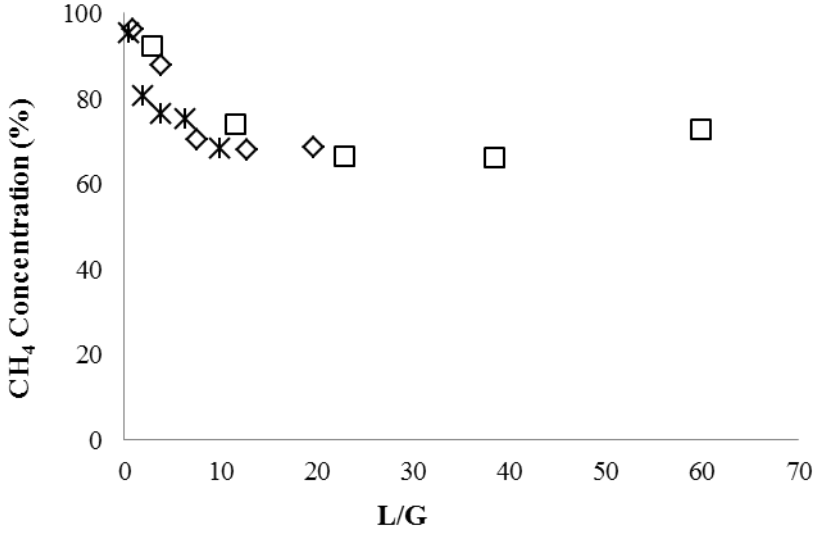


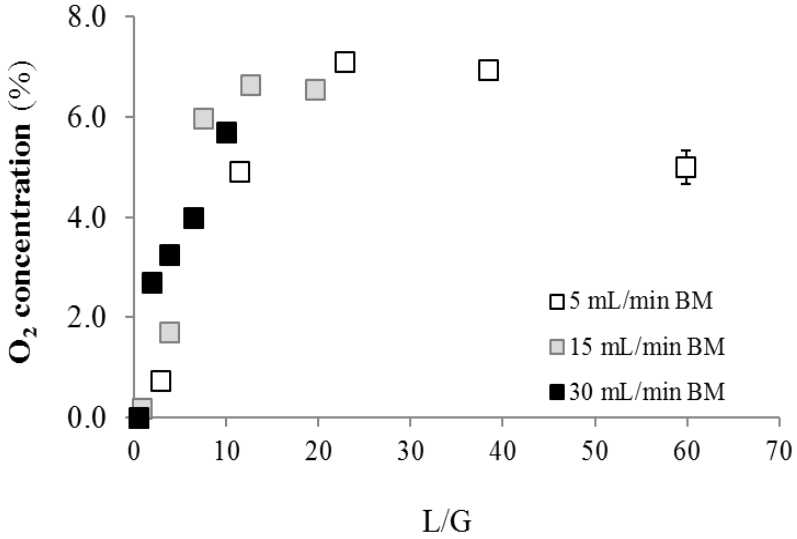
Key operational parameter: Recycling Liquid/Biogas ratio

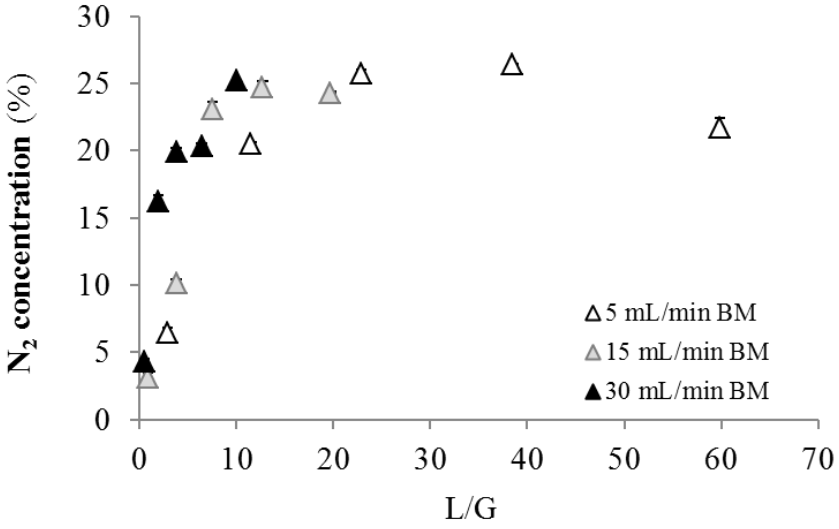
Photosynthetic Upgrading Optimization

INFLUENCE OF L/G RATIO









Photosynthetic Upgrading Optimization

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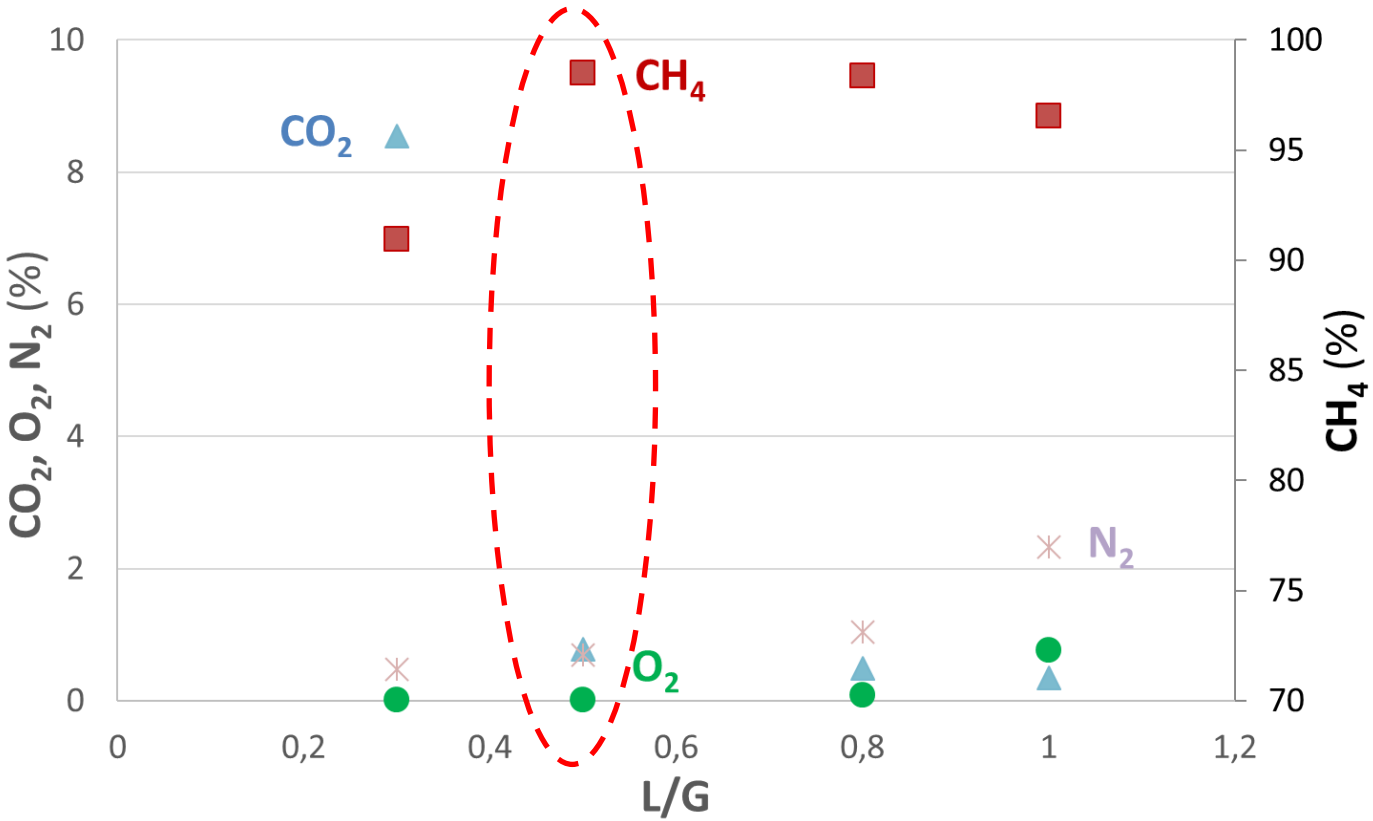
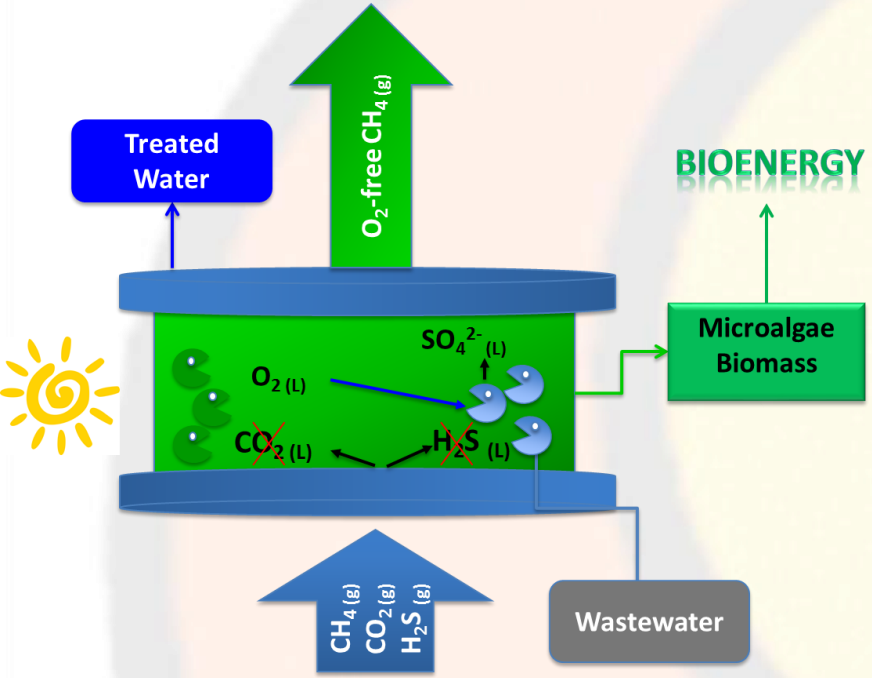
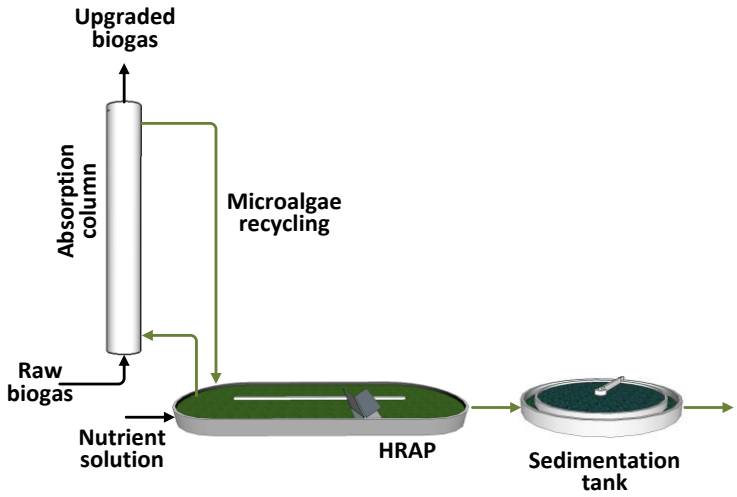
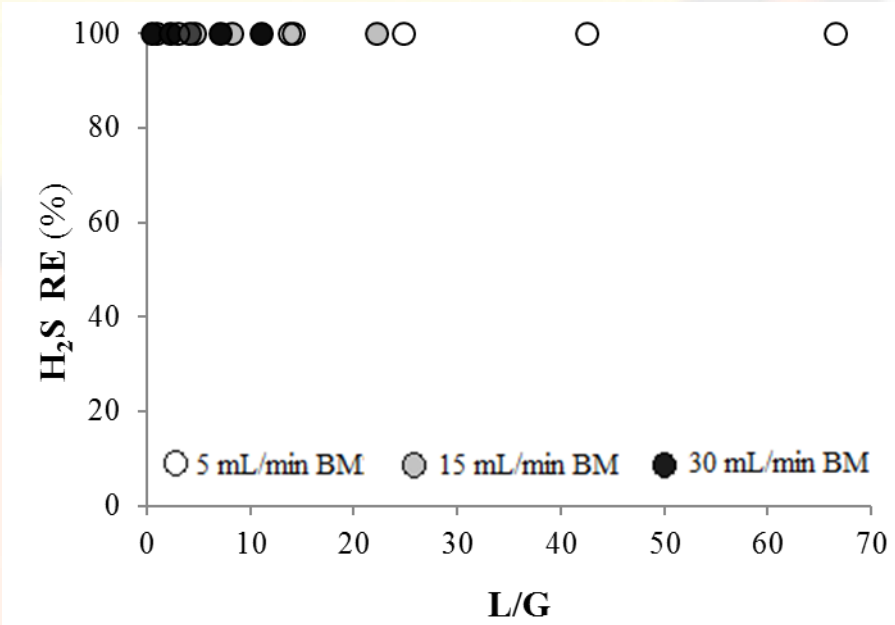


Photosynthetic Upgrading Optimization



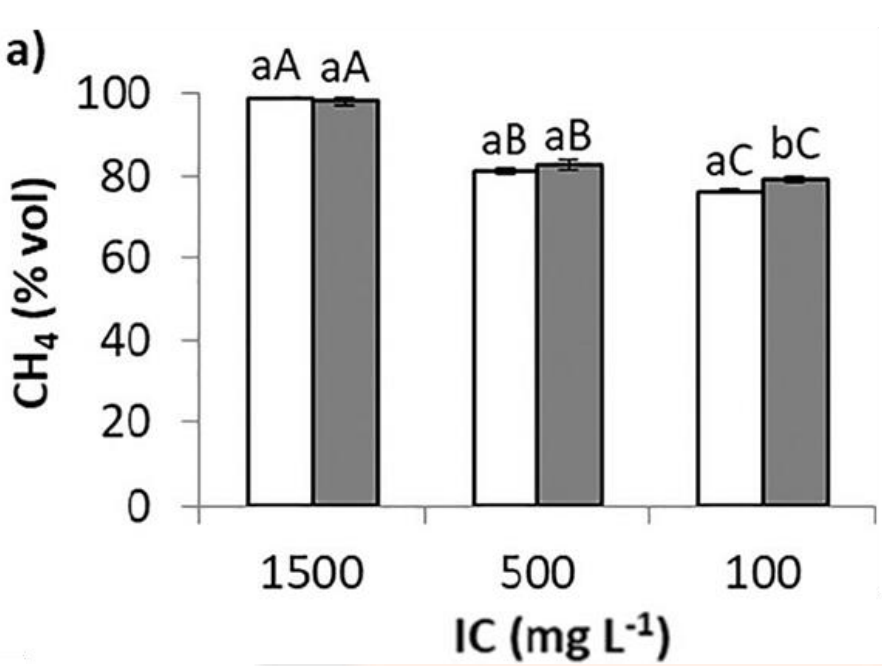
- The high pH value→ High H_2S mass transfer
- RE-H_2S > 99 %

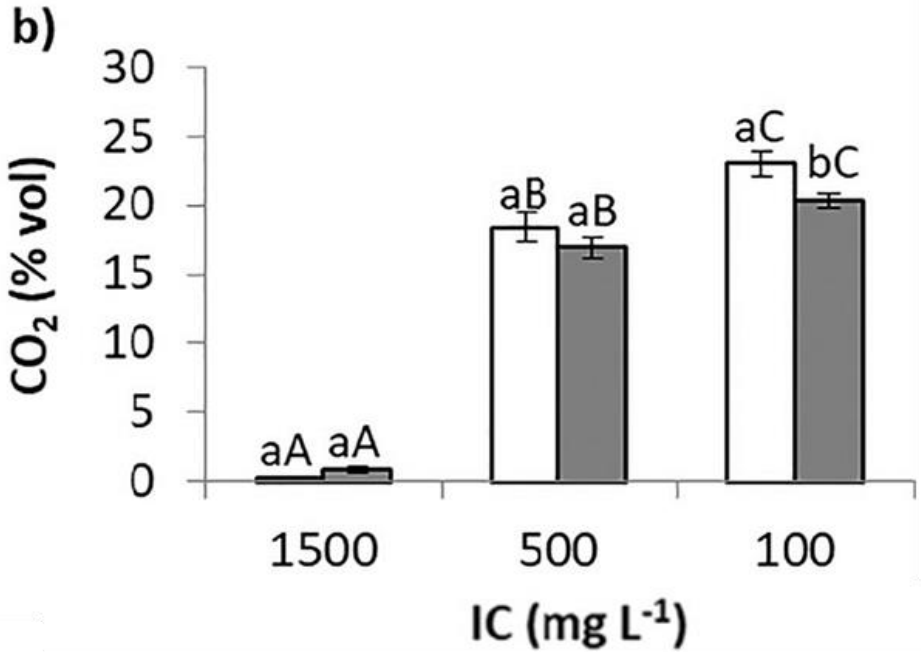




Photosynthetic Upgrading Optimization

INFLUENCE OF ALKALINITY AND TEMPERATURE





Photosynthetic Biogas Upgrading

180 L

SOSTCO2 Proyecto CENIT

32 m²

INCOVER

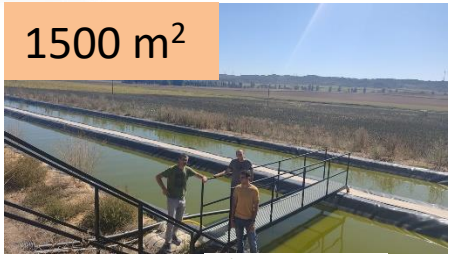
aqualia

270 m²

URBIOFIN urban biorefinery

urbaser

1500 m²



Copiso

LIFE SMART AGROMOBILITY

Photosynthetic Biogas Upgrading

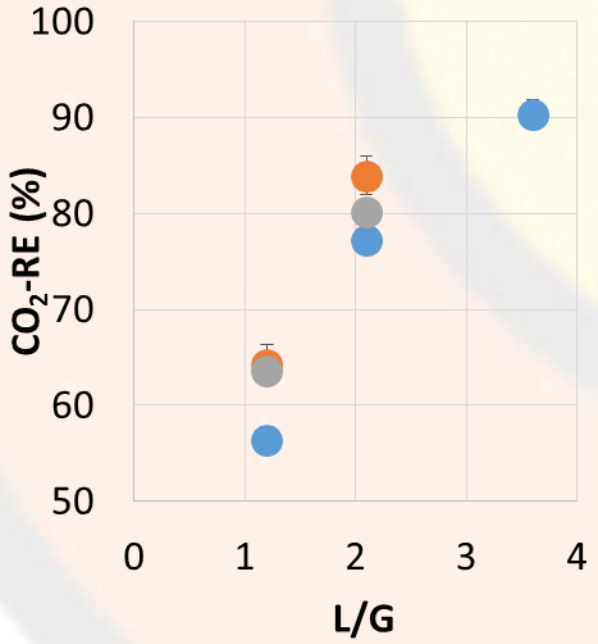
DEMO PILOT PLANT IN CHICLANA

Photosynthetic Biogas Upgrading

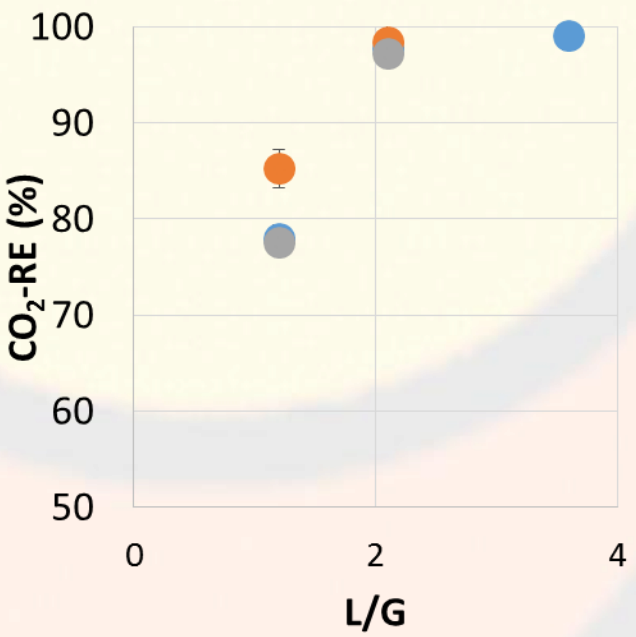
DEMO PLANT at Chiclana de la Frontera

CO_2 removal efficiencies at biogas flowrate of 274±12 (●), 370 ±7(●) and 459 ±36 (●) L/h

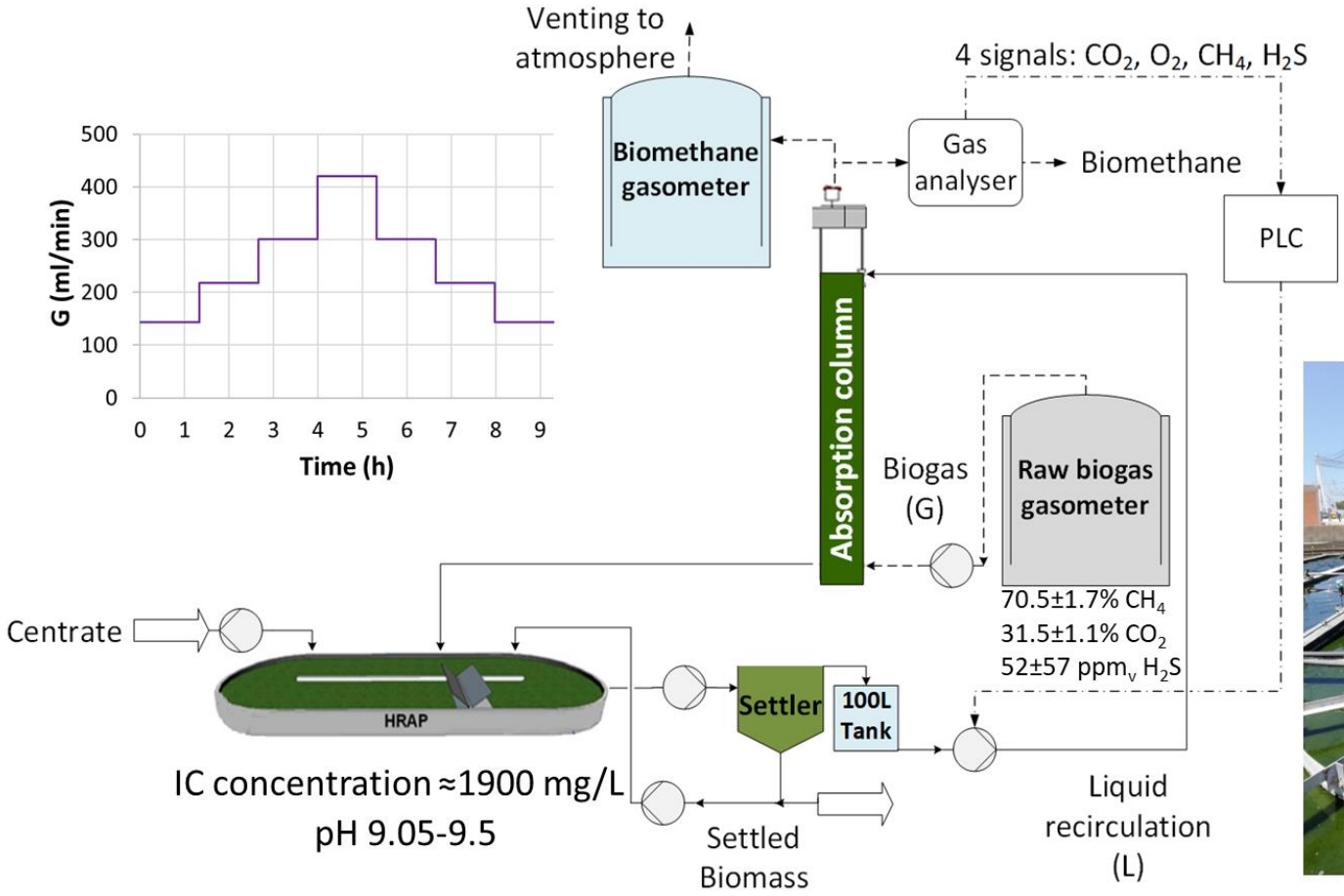
Domestic Wastewater,



Centrate



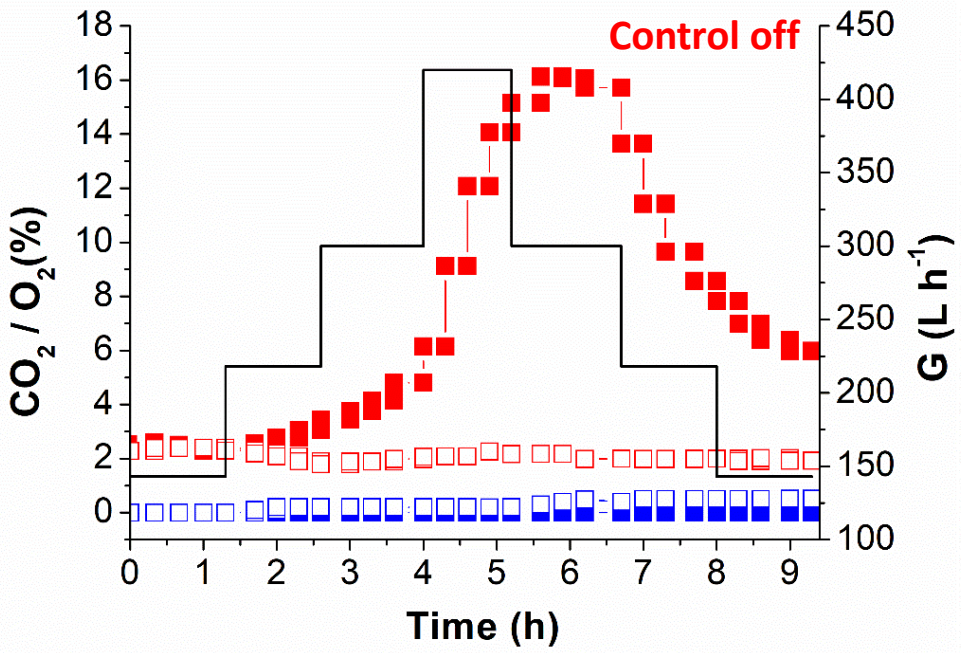
PROCESS CONTROL

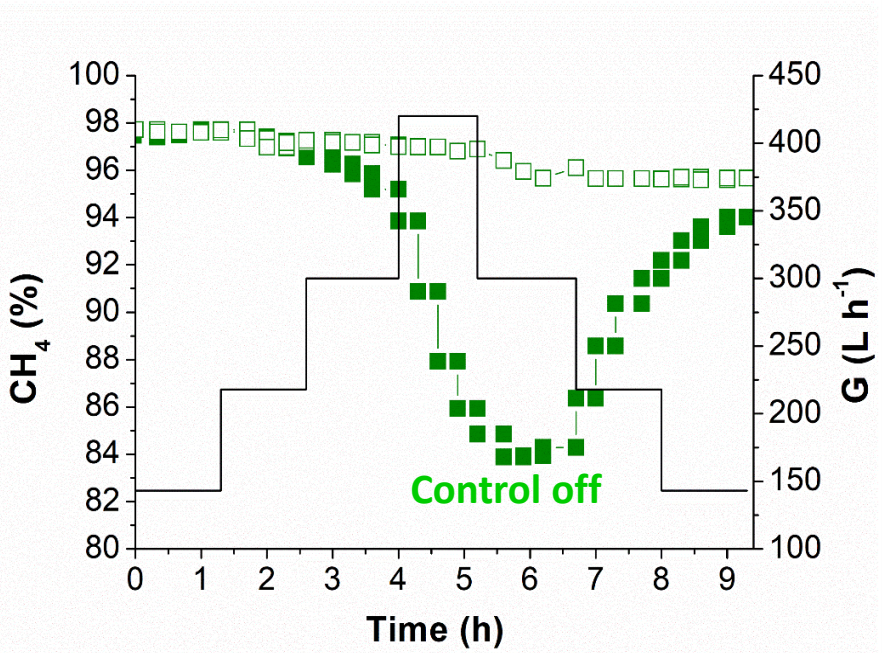


CO_2 and O_2 content in upgraded biogas (set point):
$[CO_2]sp = 2.0\%$
$[O_2]sp = 1.0\%$

Photosynthetic Biogas Upgrading

ROBUSTNESS TOWARDS BIOGAS FLOW RATE VARIATIONS





Photosynthetic Biogas Upgrading & Nutrient Recovery

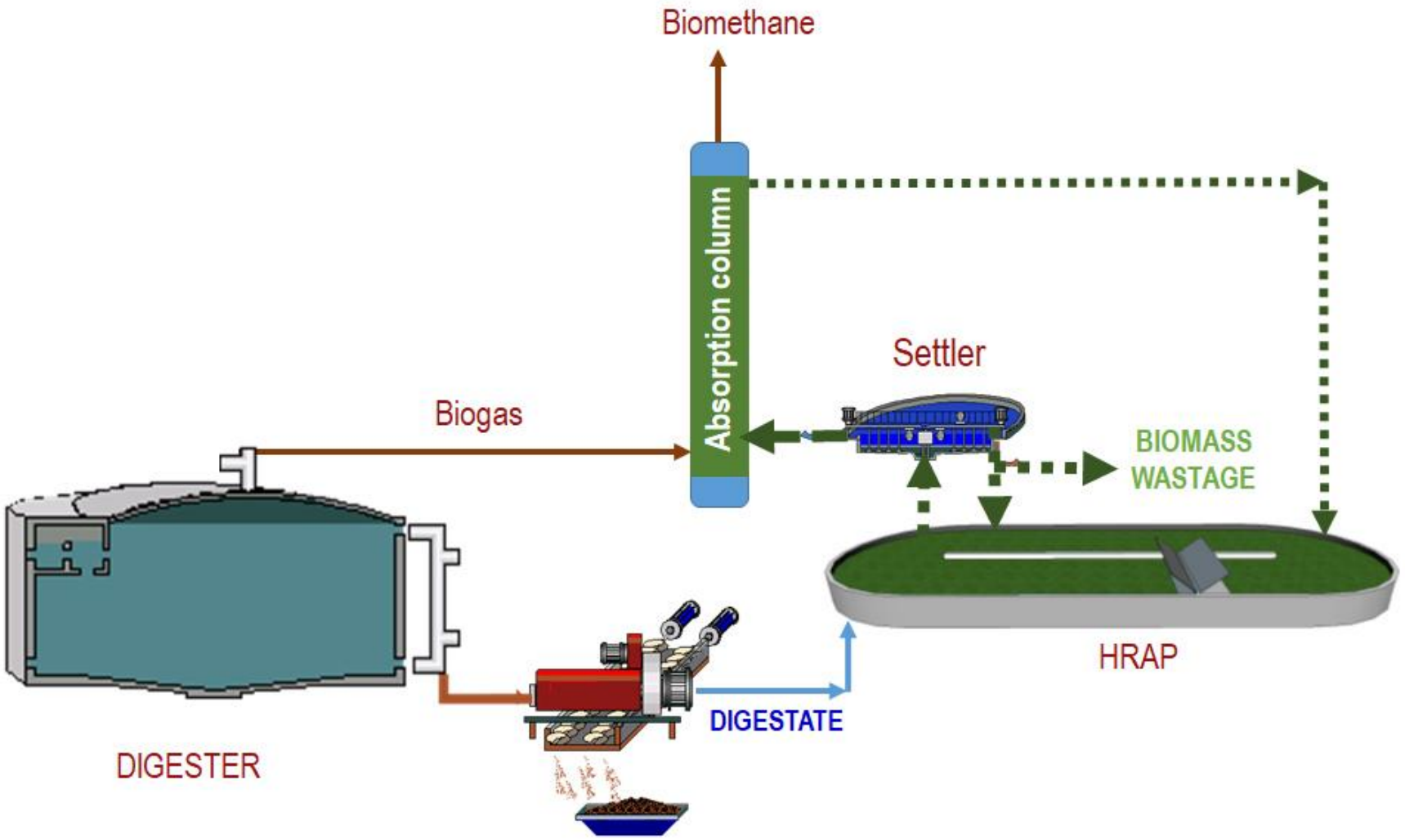
N = 600-4000 mg/L
P = 100-500 mg/L

[Microalgae]=7-50 g/L

Low Photosynthetic Efficiency↓↓

Need to develop new operational strategies to operate biogas upgrading processes with digestates

Photosynthetic Biogas Upgrading & Nutrient Recovery



Photosynthetic Biogas Upgrading & Nutrient Recovery

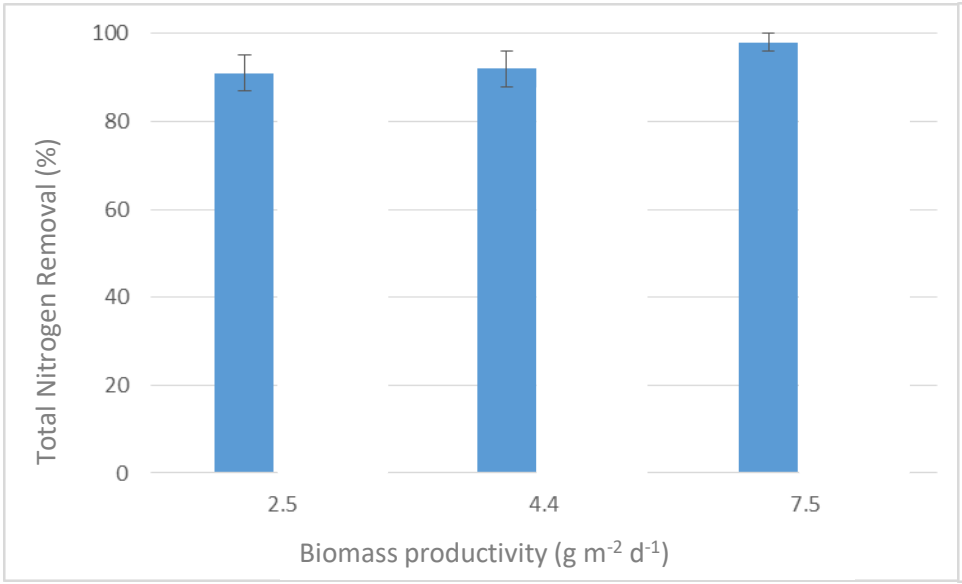
Contents lists available at ScienceDirect

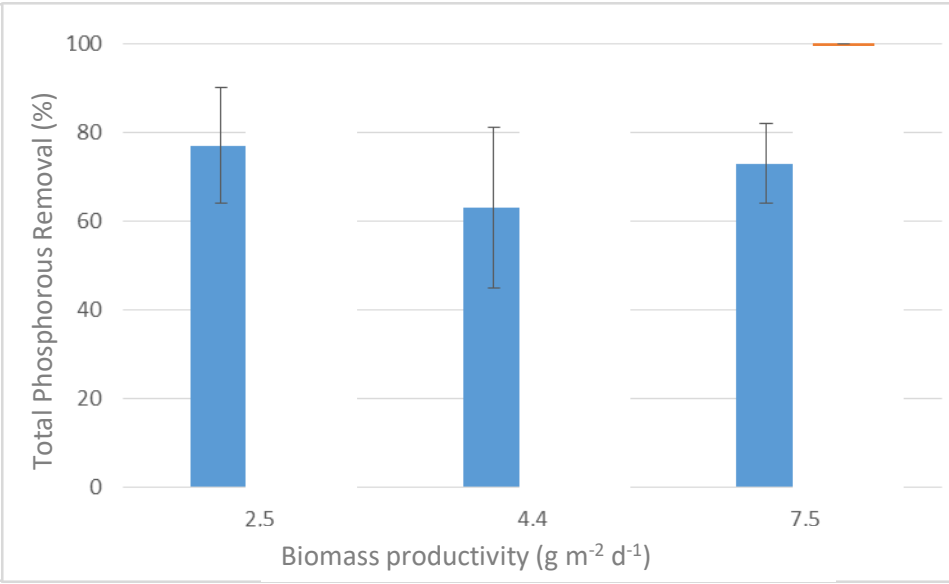
Algal Research

journal homepage: www.elsevier.com/locate/algal

Photosynthetic biogas upgrading to bio-methane: Boosting nutrient recovery via biomass productivity control

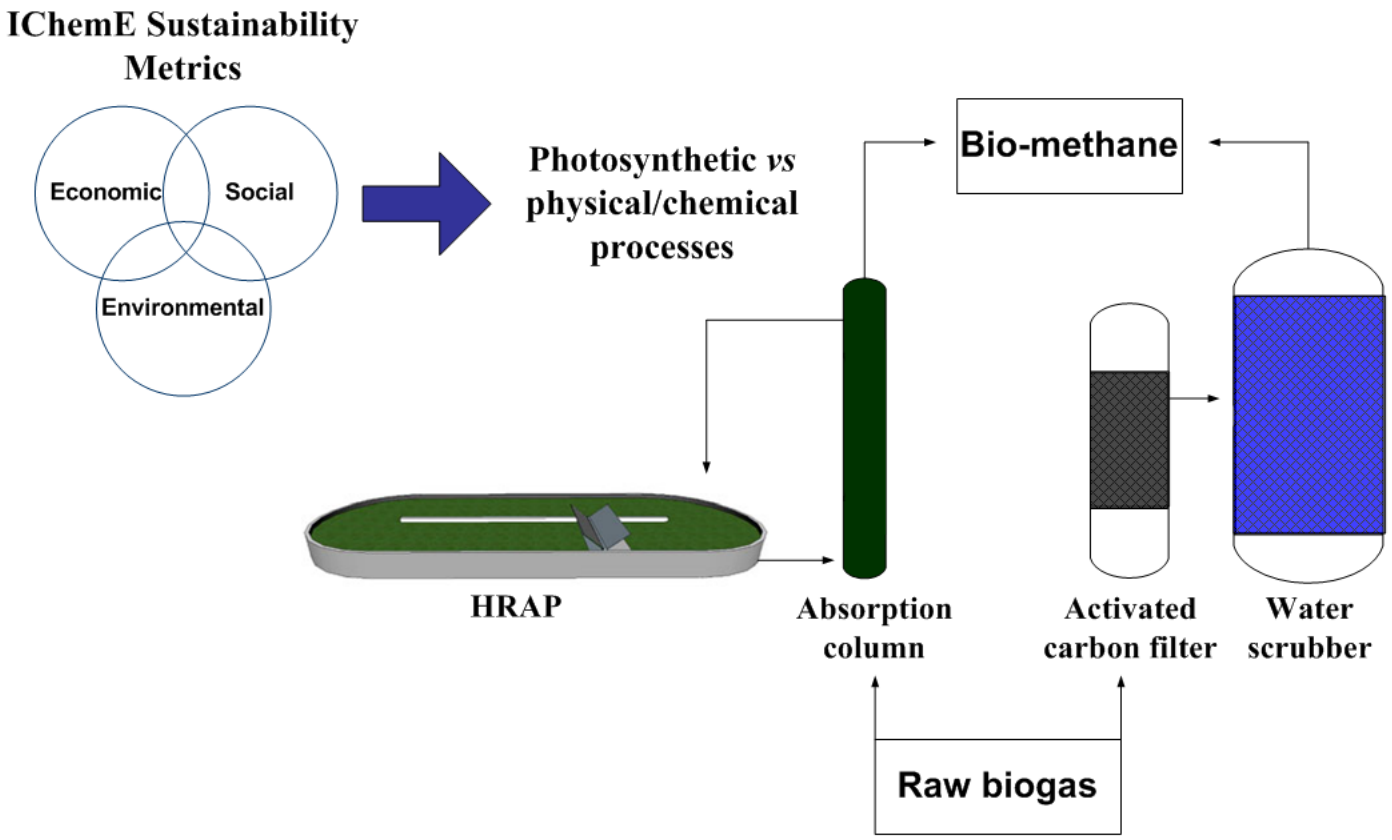
Alma Toledo-Cervantes [a], Mayara L. Serejo [b], Saúl Blanco [c,1], Rebeca Pérez [a], Raquel Lebrero [a], Raúl Muñoz [a,*]





Removal

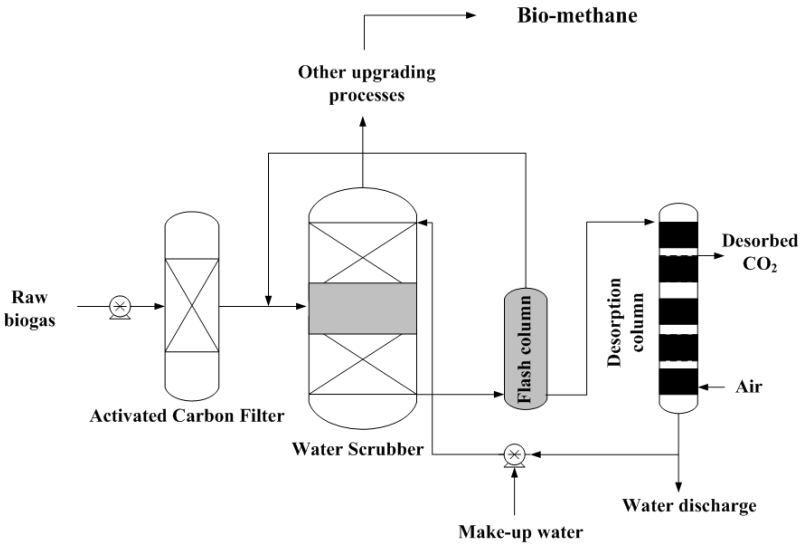
Preliminary Sustainability Analysis



REFERENCE FLOW RATE: 300 Nm^3/h

Preliminary Sustainability Analysis

Activated Carbon + Water Scrubber *Versus* Photosynthetic Biogas Upgrading



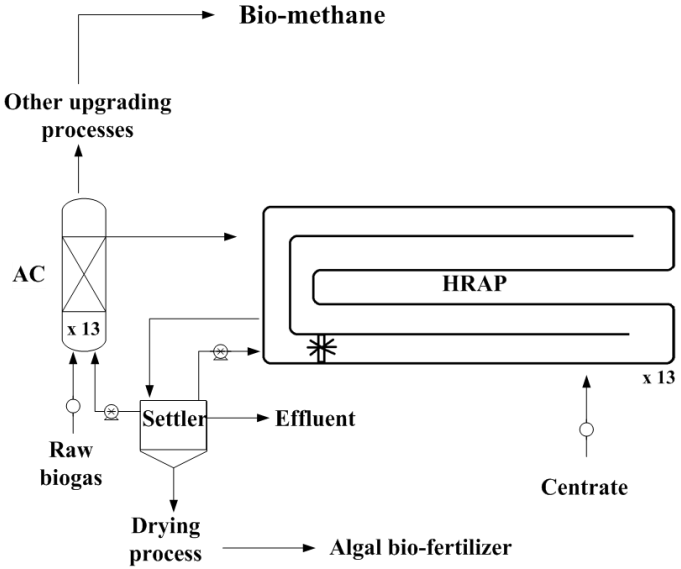


Table S1. Investment costs of a ACF-WS for the upgrading of 300 $Nm^3\ h^{-1}$ of biogas

	Cost	Units	Total cost (€)	References
Land	100	€ m^{-2}	10 000	INE, 2015
Activated carbon filter	129	€ $(Nm^3/h)^{-1}_{treated\ biogas}$	38 766	Xiao *et al*. (2008)
Water scrubber	3500	€ $(Nm^3/h)^{-1}_{treated\ biogas}$	1 050 000	SGC Rapport 2013:270

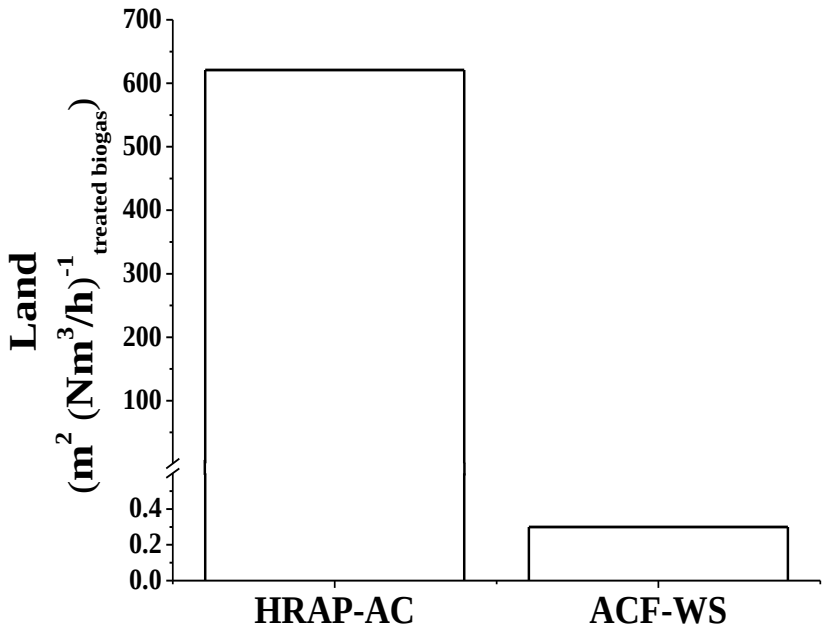
Table S2. Investment costs of the HRAP-AC for the upgrading of 300 $Nm^3\ h^{-1}$ of biogas

	Cost	Units	Total costs (€)	References
Land	10 127	€ ha^{-1}	188 712	MAGRAMA, 2014
HRAP construction	26 616	€ ha^{-1}	356 382	Craggs *et al*., 2012; Lundiquist *et al*., 2010
Paddlewheel stations	35 400	€ ha^{-1}	474 006	Craggs *et al*., 2012;
Screw press	86 000	€ $unit^{-1}$	86 000	HUBER Technology, Germany
Solar dryer	325 000	€ $unit^{-1}$	650 000	HUBER Technology, Germany
AC	3 980	€ $unit^{-1}$	51 745	Delf Grupo España S.L.
Gas diffusers	250	€ $(10\ units)^{-1}$	3 250	Xylem Inc.

Preliminary Sustainability Analysis

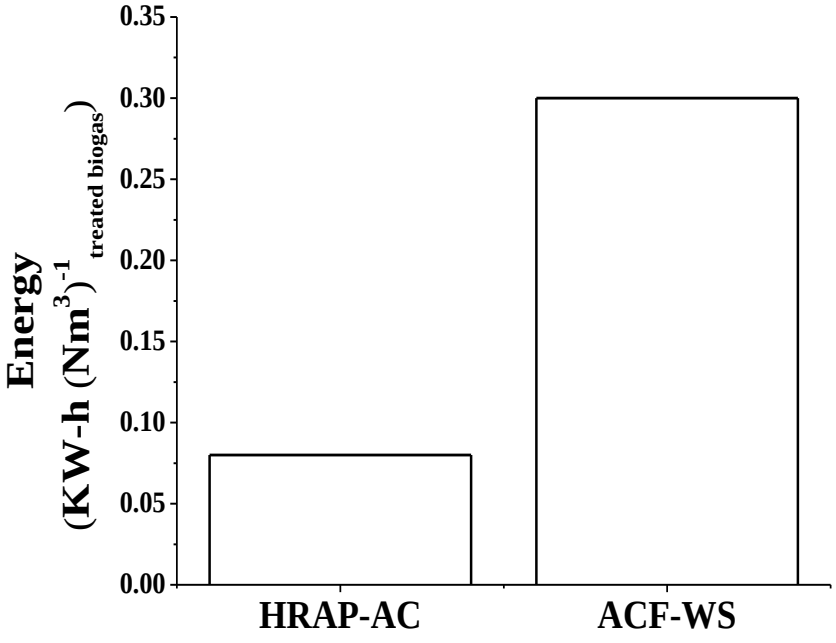
Land Requirements

a)

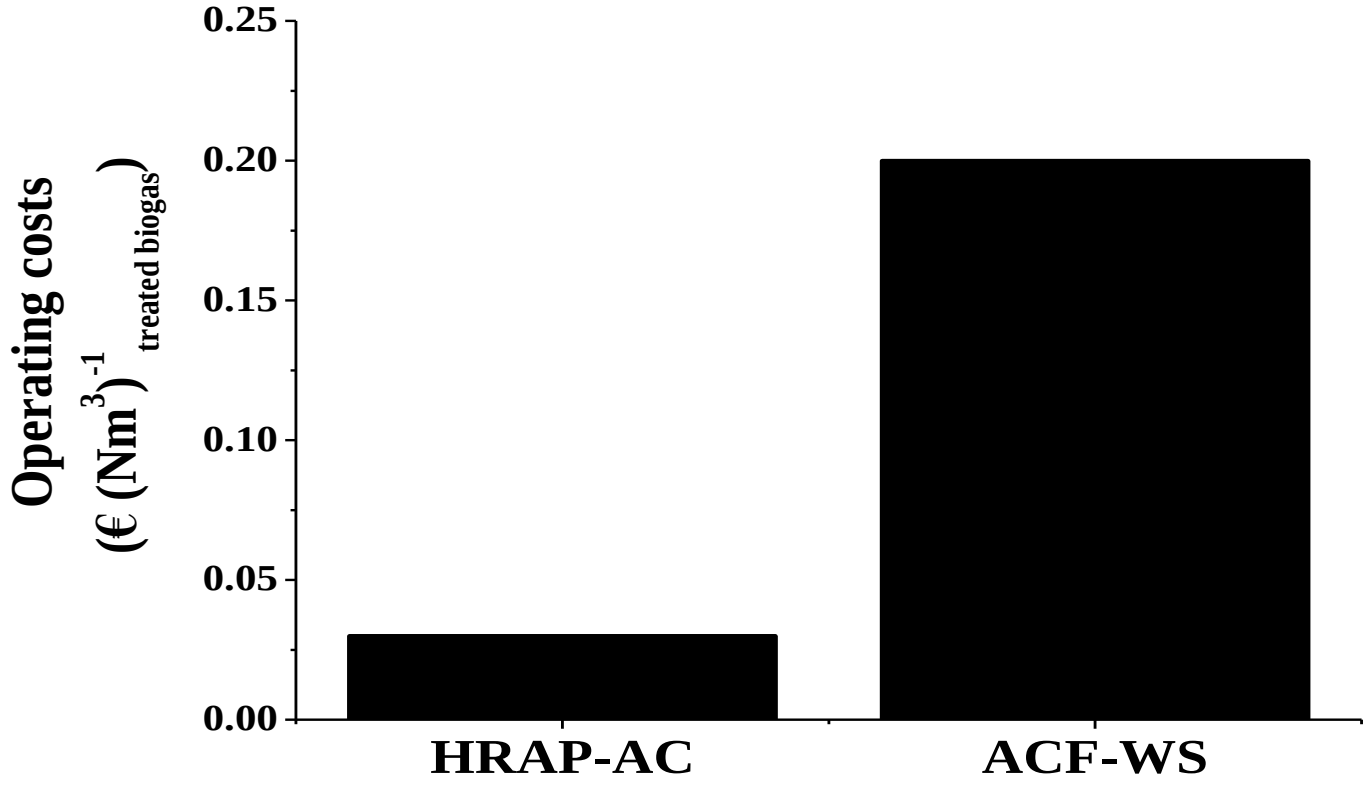


Energy Consumption

b)



Preliminary Sustainability Analysis



Take home Message

Biogas Upgrading market dominated by physical/chemical Technologies → High Operating Cost & Environmental Impact

✓ Algal-Bacterial Processes have shown a similar CO_2 and H_2S removals & high robustness but with:

- Lower operating costs and environmental impacts
- No need for previous removal of particles/H_2O/siloxanes
- Tested at pilot scale
- Nutrient recovery from digestate

✓ Photosynthetic upgrading allows for simultaneous H_2S & CO_2 removal

✓ Alkalinity, pH and L/G identified as key operational parameters

✓ Process control entails high process robustness

Thank you for your Attention

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