This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691911

Technology Description (TD) for

Biogas Upgrading Technologies

Contact Information:

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	Date (of filling the TD):	25.10.2017		

Technology Description:

NAME OF TECHNOLOGY	Algal-bacterial systems for biogas upgrading
ASSIGNMENT OF TECHNOLOGY	Level TRL 5-7
TECHNICAL READINESS LEVEL **TRL 1** - basic principles observed **TRL 2** - technology concept formulated **TRL 3** - experimental proof of concept **TRL 4** - technology validated in lab **TRL 5** - technology validated in relevant environment (industrially relevant environment in case of key enabling technologies) **TRL 6** - technology demonstrated in relevant environment (industrially relevant environment in case of key enabling technologies) **TRL 7** - system prototype demonstration in an operational environment **TRL 8** - system completed and qualified **TRL 9** - actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)	1 2 3 4 **5** 6 7 8 9
What is the core innovation? (Please explain here what is innovative on this technology and which problem does the	The core is this technology is the operational conditions implemented to achieve a simultaneous H2S and CO2 removal in a single

technology solve.)		step process, which is the main advantage compared to conventional biogas upgrading technologies
Vision of the innovation (Please describe here what impact you see for the future)		An implementation in small-medium size facilities will allow the use of this technology to produce autogas at low operating costs
What are the R&D needs for your technology? (Are there any barriers or challenges which still need to be overcome?)		Process performance at large scale under outdoors conditions in North European countries
TECHNOLOGY/EQUIPMENT AVAILABILITY		
PATENT RIGHTS		NO
METHOD OF MAKING THE TECHNOLOGY AVAILABLE	*Licence selling*	NO
	Licence granting	NO
POSSIBLE END USERS OF TECHNOLOGY	*Please name end users/ contacts that should be invited to project workshops*	Wastewater treatment plant utilities, urban waste or livestock treatment facilities

Description of the technology/equipment:

Brief description of the biotechnology:

Microalgae-based processes allow for a simultaneous CO_2 and H_2S removals from biogas under an innovative, environmentally friendly and low-cost operation. This biotechnology is based on the simultaneous CO_2 consumption by microalgae mediated by photosynthesis and the oxidation of H_2S to SO_4^{2-} by sulphur oxidizing bacteria or chemical oxidation using the O_2 produced by microalgae. The economic feasibility and sustainability of this process can be enhanced if microalgae are cultivated in wastewaters, which would entail a simultaneous biogas upgrading and wastewater treatment (Fig. 1).

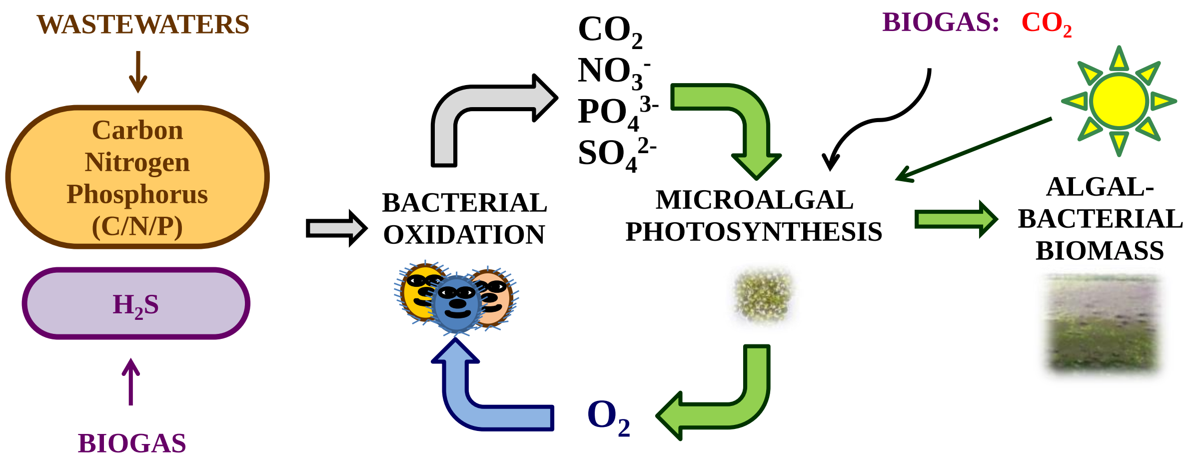

Figure 1. Algal-bacterial synergistic interactions during the simultaneous wastewater treatment and biogas upgrading.

<u>Equipment of the biotechnology</u>:

This biotechnology has been implemented and optimized throughout several research studies carried out in a 180 L high rate algal pond (HRAP) interconnected to a 2.5 L external absorption column (AC) through an external liquid recirculation (Fig. 2). In this regard, CO_2 and H_2S are transferred to the liquid phase in the AC and assimilated by microalgae or oxidized, respectively, in the HRAP. Thus, the final biomethane is obtained at the top of the AC. Biomass harvesting has been performance by sedimentation or coagulation/flocculation in an 8 L settler (Fig. 2). This harvested biomass constitutes an important source for biofuels or biofertilizers' production.

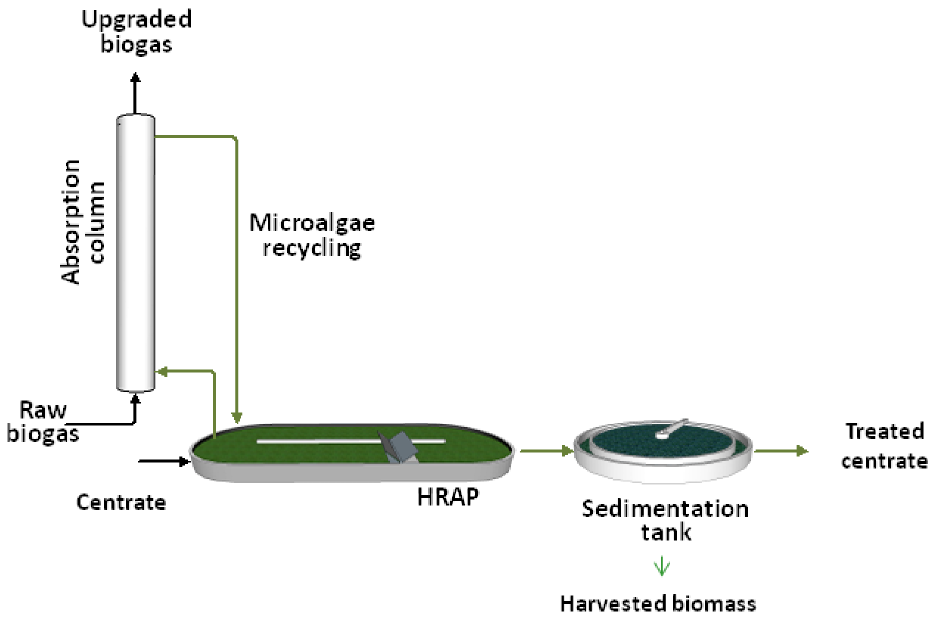

Figure 2. Experimental set-up for simultaneous biogas upgrading and centrate treatment.

<u>List of the main published articles using this biotechnology by the microalgae-VOC research group (UVa)</u>:

Alcántara C., García-Encina P., Muñoz R., 2015. Evaluation of simultaneous biogas upgrading and treatment of centrates in a HRAP through C, N and P mass balances. Water Sci. Technol. 72, 150-157.

Bahr M., Díaz I., Domínguez A., González-Sánchez A., Muñoz R., 2014. Microalgal-biotechnology as a platform for an integral biogas upgrading and nutrient removal from anaerobic effluents. Environ.Sci. Technol. 48: 573-581.

Muñoz R., Meier L., Díaz I., Jeison D., 2015. A review on the state-of-the-art of physical/ chemical and biological technologies for biogas upgrading. Rev. Environ. Sci. Biotechnol. 14: 727-759.

Posadas E., Serejo M. L., Blanco S., Pérez R., García Encina P.A., Muñoz R., 2015. Minimization of Biomethane Oxygen Concentration during Biogas Upgrading in Algal-Bacterial Photobioreactors. Algal Res. 12: 221-229.

Posadas E., Szpak D., Lombó F., Domínguez A., Díaz I., Blanco S., García-Encina P.A., Muñoz R., 2016. Feasibility study of biogas upgrading coupled with nutrient removal from anaerobic effluents using microalgae-based processes. J. Appl. Phycol. DOI: 10.1007/s10811-015-0758-3.

Posadas E., Marín D., Blanco S., Lebrero R., Muñoz R., 2017. Simultaneous biogasupgrading and centrate treatment in an outdoors pilot scale high rate algal pond. Bioresour. Technol.

Serejo M., Posadas E., Boncz M., Blanco S., Garcia-Encina PA., Muñoz R., 2015. Influence of biogas flow rate on biomass composition during the optimization of biogas upgrading in microalgal-bacterial processes. Environ. Sci. Technol. 49 (5): 3228-3236.

Toledo-Cervantes A., Serejo M., Blanco S., Pérez R., Lebrero R., Muñoz R., 2016. Photosynthetic biogas upgrading to bio-methane: Boosting nutrient recovery via biomass productivity control. Algal Res. 17, 46-52.

Toledo-Cervantes A., Madrid-Chirinos C., Cantera S., Lebrero R., Muñoz R., 2017. Influence of the gas-liquid flow configuration in the absorption column on photosynthetic biogas upgrading in algal-bacterial photobioreactors. Bioresour. Technol. 225, 336-342.

Technical Data:

Parameter		Value (please fill or tick) If value not available, please give estimate (and indicate with *).	**Comments** (e.g. which condition does the entered value correspond to?)
Current technology	Upgrading capacity of technology at current TRL-level (Nm³ raw gas/h)	0.4 m3/h	
Data basis for following data list	1.: market ready stage of technology (based on test runs of current techn.) **<u>Please only use 2. or 3. if 1. not at all possible.</u>** 2.: market ready stage of technology (based on estimate) 3.: current level (TRL) of technology	1 ☐ (preferably) 2 ☐ 3 ☒	
Technical efficiency	Methane content in raw gas (%)	68 - 71	
	Methane content in product gas (%)	≈ 90 -97	
Capacity	Flow rate (range) /upgrading capacity (Nm³ raw gas/ h)	< 300	
	Flow rate biomethane (Nm³/h)	< 220	
	Possible range for upscaling	< 300	
Data for assessment of economical added value, possible contribution to GHG-reduction	Electricity demand (kWhel/Nm³ raw gas)	0.085 kWh/m3	Simultaneous removal of H2S and CO2
	Heat demand (kWhth/Nm³ raw gas)	0	
	Chemical/additives demand (kg/h or kg/Nm³ raw gas)	Not required	
	Demand of other substances (kg/h or kg/Nm³ raw gas)	Not required	

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and availability	Biomethane slip (range in % of biomethane production)	2 %	
	Delivery pressure at exit of upgrading plant (bar_{abs})	Atmospheric	
	Full load hours (h/a)	8000	
	Exhaust gas treatment	Not required	
	Usable heat (external) through heat extraction (kWh_{th}/Nm^3 raw gas)	Not applicable	
	Space requirement (m^2)	4 ha per 100 Nm3/h	
	Staff requirement (excluding maintenance) (h/a)	200	
	Specific capital costs (excluding project development, planning, permission and additional building costs) (€/Nm³/h raw gas)	Please give exact specific cost if possible, if not please specify range. ☒ < 4.000 €/Nm³/h ☐ 4.000 - 6.000 €/Nm³/h ☐ 6.000 € - 8.000 €/Nm³/h ☐ > 8.000 €/Nm³	Simultaneous removal of H2S and CO2
	Maintenance costs (including spare parts such as new membranes, staff) (€/a or €/operating hour)	Not data available yet	
	Production costs (€/Nm³ biomethane)	0.04 €/ (Nm^3)	
	Expected lifetime of unit (years)	20 a	
Flexibility	Start-stop-flexibility	Not data available yet	
	Part-load possibility	Not data available yet	

	Is self-maintenance of technology possible?	☒ Yes, 100 % of total maintenance hours per year that can be done by operator himself ☐ No	
	Does the upgrading technology remove also H_2S or is this necessary in a separate unit?	☒ Yes,99 % of total H_2S-content of raw gas ☐ No	
	Necessity for adaptions of other parts of the plant	No	
	Advantages/disadvantages of technology	Economic, environmentally friendly, simultaneous removal of CO_2 and H_2S	
	Special application area of technology	Sunny and warm areas	