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

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	Date (of filling the TD):	23.05.2018		

Technology Description:

NAME OF TECHNOLOGY	Reactor for biogas upgrading with algae biomass
ASSIGNMENT OF TECHNOLOGY	Biological method of biogas upgrading
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	Innovative method of algae biomass immobilization

technology solve.)		
Vision of the innovation (Please describe here what impact you see for the future)		Reactor can be used for CO_2 removal from biogas or exhaust
What are the R&D needs for your technology? (Are there any barriers or challenges which still need to be overcome?)		Technology should be tested in bigger scale
TECHNOLOGY/EQUIPMENT AVAILABILITY		
PATENT RIGHTS		YES/~~NO~~
METHOD OF MAKING THE TECHNOLOGY AVAILABLE	*Licence selling*	YES/~~NO~~
	Licence granting	YES/~~NO~~
POSSIBLE END USERS OF TECHNOLOGY	*Please name end users/ contacts that should be invited to project workshops*	Small biogas plant

Description of the technology/equipment:

The reactor for biogas upgrading with algae biomass has the following structure:

The housing of the photobioreactor device (1) has the shape of a tower tank, divided by partitions into segments of a number of one to several hundred segments. The dividing partitions are perforated grids (2) on which the biomass of algae or cyanobacteria is placed in the form of capsules (3) which have a diameter of 5 mm to 40 mm in their cross section. For the selection of capsule diameter, type of gases, type of algae or cyanobacteria, number of capsule layers, light intensity and the like are decisive.

The outer envelope (4) of the capsule (3) is made of a porous material having a pore size of 5 µm to 100 µm, which allows the excessive biomass of algae or cyanobacteria to flow out of the capsule (3). The outer envelope (4) may be created on the biomass of algae or cyanobacteria previously formed in the form of a capsule, for example by coating it with gel mass or by introducing the biomass of algae or cyanobacteria to the prepared outer envelope (4), for example, in the form of a perforated plastic material. Into the inside of the biomass of algae or cyanobacteria in capsule (3), a light tube (5) is brought which is ended with a tip (21) of a material scattering light throughout the capsule (3) in the direction of its outer envelope (4). The second end of the light tube (5) is connected to the light source (6).

Below the lowermost perforated grid (2), in the housing of the photobioreactor device (1), there is a conduit inlet (7) for a CO_2 containing gas, which is connected to a pump (8) conveying the gas with CO_2 from a retention tank (9) that contains CO_2.

In the overhead protection in the housing of the device (1), an outlet duct (10) for gases is mounted.

Sprinkler nozzles (11) are located above the biomass of algae or cyanobacteria in capsules (3) and have a connection to a culture medium dosing pump (12) and to a culture medium tank (13), as well as to a flushing pump (14) and to a retention tank (15) with clarified water.

The retention tank (15) is fluidly connected by a conduit (22) to a separation tank (16) for the excessive biomass of algae or cyanobacteria.

An outlet duct (17) discharges the excess of the biomass of algae or cyanobacteria from the bottom of the photobioreactor device (1) to the separation tank (16) for the excessive biomass of algae or cyanobacteria and this excess of the biomass is discharged further, outside the photobioreactor, by a drain conduit (19) with a valve (18).

The formed biomass of algae or cyanobacteria (3) has the shape of capsules of a diameter of 5 mm to 40 mm and is covered with the outer envelope (4) having a perforation of a diameter of 5 µm to 100 µm. The outer envelope (4) is in the form of a layer of gel substance or a layer formed from a perforated plastic coating.

The light is supplied with a separate light tube (5) into the biomass of algae or cyanobacteria to each capsule (3). Into the biomass of algae or cyanobacteria in capsule (3), gases containing CO_2 and liquid culture medium which is periodically fed from the top, from the sprinkler nozzles (11), are periodically introduced.

The generated excessive algal biomass is periodically flushed from the top, directed to the separation tank (16) and discharged outside the photobioreactor, by the drain conduit (19).

The light from the light source (6) is continuously supplied to the formed biomass of algae or cyanobacteria in capsules (3) by the light tubes (5). The light source (6) may be sunlight or a light generator of different wavelength of light from 300 nm to 800 nm.

A portion of gas containing CO_2, accumulated in the tank (9) and conveyed by the pump (8) is periodically introduced into the housing of the photobioreactor (1) tank. When conveying the gas that contains CO_2, it penetrates the algal biomass in capsules (3) through the outer envelope (4), displacing, from the algal biomass, gaseous metabolic products which are discharged by the outlet duct (10) for gases.

When the pump (8) completes its operation, the pump (12) starts operating, through which the liquid culture medium is conveyed from the culture medium tank (13) to the sprinkler nozzles (11). The culture medium flows over outer surfaces of the envelopes (4) and penetrates into the algal mass in capsules (3), contributing, combined with the supplied light energy and CO_2, to the increase of the algal biomass. The algal biomass escapes from the capsules (3) through the perforated outer envelope (4) and is periodically flushed with the liquid, when pumping the liquid with the flushing pump (14) from the retention tank (15). The liquid was obtained after the previous separation of the excessive algal biomass in the separation tank (16) into which it flows from the entire volume of the housing of the photobioreactor device (1), together with the flushing liquid, by the outlet duct (17). After periodical opening of the valve (18), the condensed excessive algal biomass is removed outside the photobioreactor by the conduit (19), and the mixture of unused liquid medium and liquid metabolic products flows out partially by an outflow duct (20) outside the photobioreactor and partially returns into circulation, pumped by the flushing pump (14).

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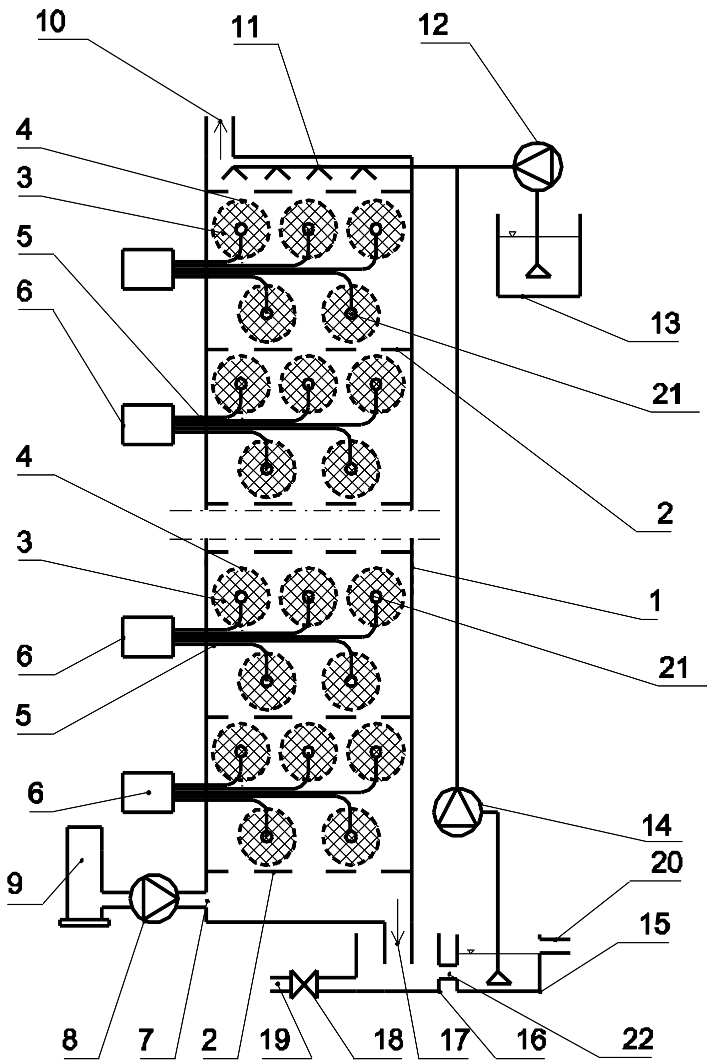

Fig. 1 Scheme of the reactor for biogas upgrading with algae biomass
(1) housing of the photobioreactor device, (2) perforated grids, (3) capsule of biomass of algae or cyanobacteria, (4) outer envelope of the capsule, (5) light tube, (6) light source, (7) CO_2 conduit inlet, (8) gas conveying pump, (9) CO_2 tank, (10) gas outlet duct, (11) sprinkler nozzles, (12) culture medium dosing pump, (13) tank with culture medium, (14) flushing pump, (15) retention tank, (16) separation tank for excess of biomass of algae or cyanobacteria, (17) outlet duct, (18) valve, (19) drain conduit, (20) outflow duct, (21) tip of the light tube inside the capsule, (22) conduit

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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)	4	
Data basis for following data list	1.: market ready stage of technology (based on test runs of current techn.) **Please only use 2. or 3. if 1. not at all possible.** 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 (%)	50-65	
	Methane content in product gas (%)	85-90	
Capacity	Flow rate (range) /upgrading capacity (Nm³ raw gas/ h)	4	
	Flow rate biomethane (Nm³/h)	2.5-3.0	
	Possible range for upscaling	100 Nm³/h raw biogas	
Data for assessment of economical added value, possible contribution to GHG-reduction	Electricity demand (kWhel/Nm³ raw gas)	1.5 kWhel/Nm³	
	Heat demand (kWhth/Nm³ raw gas)	0.2 kWhth/Nm³	
	Chemical/additives demand (kg/h or kg/Nm³ raw gas)	not necessary	
	Demand of other substances (kg/h or kg/Nm³ raw gas)	not necessary	

and availability	Biomethane slip (range in % of biomethane production)	0	
	Delivery pressure at exit of upgrading plant (bar $_{abs}$)	Normal pressure	
	Full load hours (h/a)	8000	
	Exhaust gas treatment	yes	
	Usable heat (external) through heat extraction (kWh_{th}/Nm^3 raw gas)	no	Please indicate temperature
	Space requirement (m^2)	5	
	Staff requirement (excluding maintenance) (h/a)	500	
	Specific capital costs (excluding project development, planning, permission and additional building costs) (€/Nm^3 raw gas/h)	Please give exact specific cost if possible, if not please specify range. ☐ < 4.000 €/Nm^3/h ☐ 4.000 - 6.000 €/Nm^3/h x 6.000 € - 8.000 €/Nm^3/h ☐ > 8.000 €/Nm^3/h	
	Maintenance costs (including spare parts such as new membranes, staff) (€/a or €/operating hour)	4500	
	Production costs (€/Nm^3 biomethane)		Unknown in present TRL status of technology
	Expected lifetime of unit (years)	15	
Flexibility	Start-stop-flexibility	yes	Working reactor is easy to start and stop

	Part-load possibility	☐Yes, 20-50% of full capacity ☐ No	
	Is self-maintenance of technology possible?	☐Yes, ...% 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, 80-90 % of total H_2S-content of rawgas ☐ No	
	Necessity for adaptions of other parts of the plant	no	
	Advantages/disadvantages of technology	Advantages: high efficiency, obtain useful algae biomass, possibility using of wastewater/ disadvantages: high capital cost	
	Special application area of technology	Purification of burning gases	