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):	2017-09-25		

Technology Description:

NAME OF TECHNOLOGY	Ash filter
ASSIGNMENT OF TECHNOLOGY	Upgrading raw biogas to vehicle standard
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	Using a waste stream (ash) for something useful, such as cleaning raw biogas from CO2 and H2S so that it reaches vehicle fuel standard while at the same time stabilizing the

technology solve.)		ash making it possible to use as a forestry fertilizer. The problem is that current biogas upgrading technologies are too expensive for small scale application. The ashfilter technology is designed to be low cost and low tech in order to make economic sense at small scale to fill that market space.
Vision of the innovation (Please describe here what impact you see for the future)		The vision for the ashfilter technology is twofold: 1. Upgrading to vehicle fuel at farm scale enabling farmers to move towards energy autonomy; 2. Cleaning landfill gas from H2S using waste to energy (WTE) ash that has to be landfilled anyway. This would mean reduce maintenance cost of co-generation at landfills so that more landfill gas is beneficially used for energy generation rather than being flared or, worse, not even being collected.
What are the R&D needs for your technology? (Are there any barriers or challenges which still need to be overcome?)		The primary barrier is ash logistics. How to get the ash from the biomass or waste combustion plant to the biogas plant and then back to the forest or landfill depending on ash quality. This logistic works great in certain vertically integrated forestry/agricultural farms but we need to make the logistics work at a grander scale and be more generic. Promising work is being conducted within this area and we expect to solve this problem.
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*	Sala Heby Energi, Jokkmokk municipality, Sötåsens naturbruksgymnasium, Julmyra horsecenter, Sörby slakteri, lövsta egendom, Jällaskolan, MMG konsult, Swedish biogas international, Air Liquid, Biogas Systems AB, Norups gård, Wapnö Gård, Purac Puregas, Biolectric, IQlink, energiutvecklarna, Atlas Copco Compressor Technique Scandinavia, Ecobiofuel, Malmberg Water AB, Scandinavian Biogas Fuels AB.

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Description of the technology/equipment:

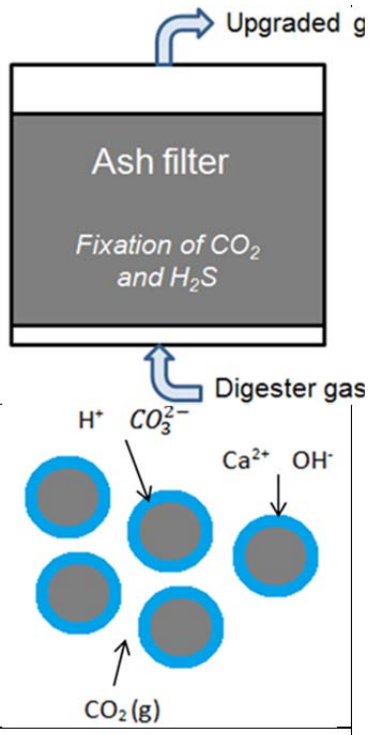
The method is based on using CaO-rich wood fuel ash utilising the principle of carbonation, i.e. calcium hydroxide ($Ca(OH)_2$) is reacting with CO_2 under the formation of calcite ($CaCO_3$). The implementation of this method is relatively simple and uses a residue with a low alternative value. Previous trials have shown a good capacity for removal of CO_2 and H_2S from the biogas and stabilisation of the ash.

The process step by step

- Dry ash mixed with water:

$$CaO(s) + H_2O(l) \rightarrow Ca^{2+} + 2OH^- + heat$$

- Loading and sealing the ash filter
- Connect to biogas flow, inlet in the bottom of the vessel



- Transformation of CO_2 to carbonate:

$$CO_2(g) \leftrightarrow CO_2(aq)$$

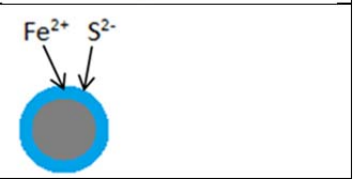
$$CO_2(aq) + H_2O(l) \rightarrow CO_3^{2-}(aq) + H^+(aq)$$

- Final step CO_2 fixation: Calcite formation

$$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s) + heat$$

- Fixation of H2S:

$$H_2S(g) \rightarrow HS^- + 2H^+$$
$$Fe^{2+} + S^{2-} \rightarrow FeS(s)$$



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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)	0-10	This is the capacity of the industrial pilot that we have running at Sötåsen
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 (%)	0 - 100	Theoretically the methane content in raw gas does not matter but in practice it is impractical to apply the ash filter for CO2 removal with anything less than 60% methane in the raw biogas since the ash consumption becomes unreasonable.
	Methane content in product gas (%)	>99%	
Capacity	Flow rate (range) /upgrading capacity (Nm³ raw gas/ h)	0 - 60	
	Flow rate biomethane (Nm³/h)	0 - 60	Assuming the the methane content in the raw gas can be 0-100% the flow rate capacity for biomethane is the same as that for raw gas.
	Possible range for upscaling	Up to 3 GWh/year	Yes but the acces to high volumes of Ca-rich ash is crusial
Data for assessment of economical	Electricity demand (kWhel/Nm³ raw gas)	< 0,02	
	Heat demand (kWhth/Nm³ raw gas)	0	

added value, possible contribution to GHG-reduction and availability	Chemical/additives demand (kg/h or kg/Nm³ raw gas)	Ash: 3,6 - 7,1 kg/Nm3 raw gas	
	Demand of other substances (kg/h or kg/Nm³ raw gas)	Water	
	Biomethane slip (range in % of biomethane production)	0 – 0,2	
	Delivery pressure at exit of upgrading plant (bar $_{abs}$)	1 atm + 1-20 mbar	
	Full load hours (h/a)	7000 - 8760	
	Exhaust gas treatment	Flaring or as combustion air to a gas boiler	The filter has no exhaust gas during operation. You do however get some exhaust gas when flushing the system after having changed filter material and this exhaust air should be flared.
	Usable heat (external) through heat extraction (kWh_{th}/Nm^3 raw gas)	No	Please indicate temperature
	Space requirement (m^2)	Ca 100 m2	Area for ash filter and gas system exclusive area for management of ash
	Staff requirement (excluding maintenance) (h/a)	200 - 300	The operation is maintained by biogas plant owner
	Specific capital costs (excluding project development, planning, permission and additional building costs) (€/Nm³ raw gas)	Please give exact specific cost if possible, if not please specify range. ☐< 4.000 €/Nm³ ☐ 4.000 - 6.000 €/Nm³ ☒ 6.000 € - 8.000 €/Nm³ ☒ > 8.000 €/Nm³	1 GWh:8500 €/Nm³/h 2 GWh:6500 €/Nm³/h
	Maintenance costs (including spare parts such as new membranes, staff) (€/a or €/operating hour)	4000 - 8000	€/a

	Production costs (€/Nm³ biomethane)	0,3	
	Expected lifetime of unit (years)	15	
Flexibility	Start-stop-flexibility	Yes	Very limited lag-time at start.
	Part-load possibility	☒Yes, 0 - 100% of full capacity ☐ No	
	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 rawgas ☐ No	
	Necessity for adaptions of other parts of the plant	Yes, but very limited	May need a gas fan to overcome pressure drop of up to 20 mbar in the filter bed.
	Advantages/disadvantages of technology	Advantages: low cost, low technology complexity, high gas purity, low methane slip, high on/off flexibility Disadvantages: High ash consumption, complicated ash logistics, limited scale-up possibilities	
	Special application area of technology	See the segment “Vision of the innovation” above	