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

Substrate Pre-Treatment Technologies

Contact Information:

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	Date (of filling the TD):	26.09.2017		

Technology Description:

NAME OF TECHNOLOGY	Kombi-Hydrolysis with Wave-Box (ultrasound)
ASSIGNMENT OF TECHNOLOGY	Physical and enzymatic disintegration of fibrous structures (plant fibres), bacteria and plant cells, as well as macromolecules like hemicellulose by cavitation and hydrolytic micro-organism
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 technology solve.)		Combination of ultrasonic & separate hydrolysis stage. Decomposition of fibers with return into the most active area of the process. On the one hand substances are made available on the other hand, viscosity will be reduced, better pumping capacity will be achieved. Hydrolysis stage combines the low-emission feeding with solids, the actual biological hydrolysis, the uniform feeding of the fermenter.
Vision of the innovation (Please describe here what impact you see for the future)		Retrofit existing plants to reduce emissions and improve efficiency
What are the R&D needs for your technology? (Are there any barriers or challenges which still need to be overcome?)		Demo operation with different substrates as well as biowaste
TECHNOLOGY/EQUIPMENT AVAILABILITY		
PATENT RIGHTS		YES
METHOD OF MAKING THE TECHNOLOGY AVAILABLE	*Licence selling*	NO
	Licence granting	YES
POSSIBLE END USERS OF TECHNOLOGY	*Please name end users/ contacts that should be invited to project workshops*	Operators of biogas plants, searching efficient technologies; Farmers wanting to use slurry and manure for biogas production; Food technology plants with organic residues like spent grain, marc, belly grass, etc.

Description of the technology/equipment:

Kombi-Hydrolysis and Wave-Box

PRV has developed both elements to enhance the disintegration of difficult degradable organic substrates – making it available for biogas production.

Combining both technologies as a pre-treatment-system, the benefits of separated hydrolysis processes and of ultrasound technology will be multiplied.

The Kombi-Hydrolysis integrates dosing of substrates, crushing, mashing and feeding of the digester as well as biochemical hydrolysis. No other dosing or crushing unit is necessary.

This synergistic technology treats especially fibrous and rough biomass suspensions (grass, manure, etc.) which are generally difficult to digest. The operator therefore remains independent of easy fermentable substrates of high quality (e.g. maize). Preferably, a continuous recirculation flow from the digester into the hydrolysis tank is processed by passing the ultrasound Wave-Box.

Cavitation effects (fig. 1 and 2) break down the biomass, therefore boosting microbiological activity inside the Kombi-Hydrolysis. The result of these intensified processes is a significantly increased biogas production (usually 10 to 25 %), achieved with small energy input.

The Wave-Box normally is directly connected and adapted to the Kombi-Hydrolysis. Nevertheless, both are also easily attachable to an existing biogas plant as stand-alone-devices.

The Wave-Box control system can be integrated into the biogas plant‘s control system via a data interface.

Optimized operation - increased plant efficiency

The Wave-Box runs in automatic (standard) or optionally in manual mode. Cutting pumps haul the pre-fermented substrate from digester or second step fermenter continuously into the Wave-Box and from there into the Kombi-Hydrolysis. While passing the ultrasound units (sonotrodes), pressure fluctuations inside of cells produce enormous cavitation forces: The fibrous parts of the substrate and cell walls break. The resulting disintegration makes any kind of substrate better available, intensifies the digestion process and sets free a number of macro-molecules destroying enzymes. By recirculating several times between digester, Kombi-Hydrolysis and Wave-Box the materials which are difficult to ferment are broken down gradually.

Increased methane yield also boosts CHP-power output. Alternatively, the operator can maintain a constant biogas and power production, while reducing expensive feedstock (i.e. maize). In addition, an increase in methane content improves the quality of the biogas. The simultaneously induced lowering of the viscosity achieved by the use of ultrasound also produces savings in the plant‘s own power consumption.

Due to permanent recording and monitoring of the main process-specific parameters, the plant operator is always able to operate the Kombi-Hydrolysis with Wave-Box optimally.

Technology of Wave-Box: High-power ultrasound technology - breaking down biomass through cavitation - the principle

Ultrasound is sound with frequencies beyond audible sound, i.e. from 20 kHz up to the megahertz range. In aqueous media, ultrasound waves cause periodic compression and extension of the water phase (fig. 1). High-intensity ultrasound is necessary to tear apart water molecules during the rarefaction phase, which results in the formation of microscopically small voids in the liquid. These voids become bubbles filled with water vapour or gas. They grow in extension phases and shrink in compression phases, until they implode.

This event is cavitation, a process under extreme (adiabatic) conditions. On a micro scale, there is a pressure of 500 bar and a temperature of about 5,000°C. Particularly large cavitation bubbles are produced within the frequency range from 20 to 100 kHz; when these bubbles collapse, they cause extreme mechanical shear forces. These forces produced by ultrasound are capable of destroying even the most robust surfaces.

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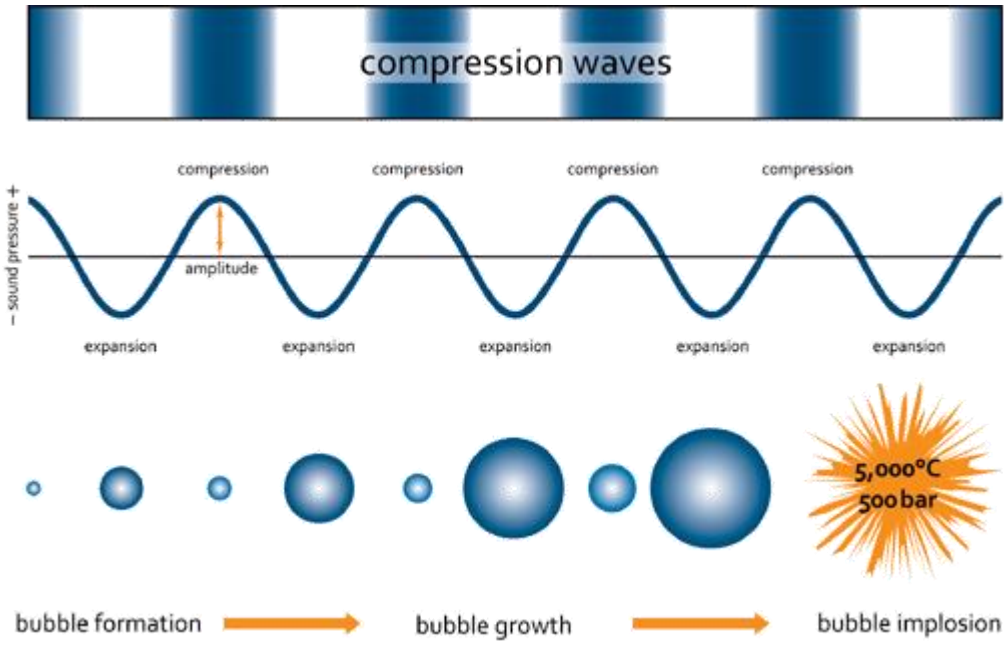

Fig. 1: Principle of cavitation caused by ultrasound

How it works - Effect on bacteria, algae and agricultural biomass

High-intensity ultrasound causes biomass to break down (fig. 2). The Wave-Box ultrasound system first decompose agglomerations of biomass material at rather low energy input (short sonication time). Further sonication opens up the biomass cells, so that the cell contents escape and dissolve. This process releases enzymes from the bacterial biomass. Hence the sonicated biomass is readily available as a substrate for active microorganisms and is degraded better in a subsequent biological degradation process.

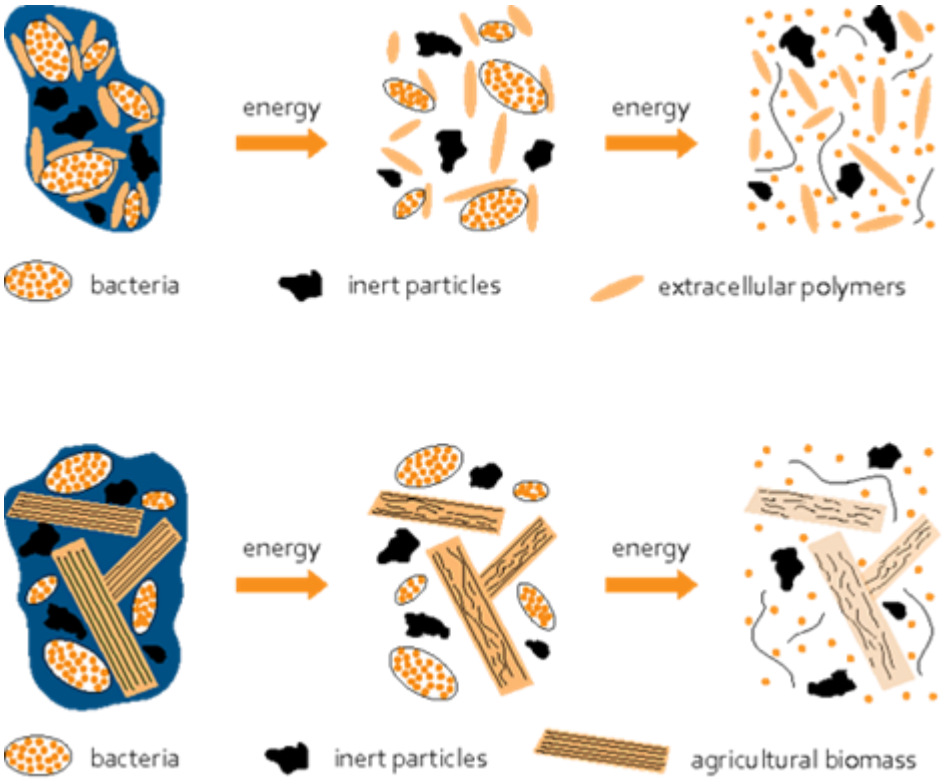

Fig. 2: Effects of cavitation on bacteria, fibrous materials and other biomass

Fig. 3: Wave-Box installation with Kombi-Hydrolysis

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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	Flow rate of technology at current TRL-level (Mg/h)	1 – 2 Mg/h	Wavebox bei 500 kWel
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	Increase in biogas production through pre-treatment technology (%)	10 - 25 %	Depending on substrate specifics and treatment quality
Capacity	Flow rate (range) (Mg/h)	1 - 3 m^3/h Wave-Box unit; 5-10 m^3/h feeding rate hydrolysis to digester	Pre-treatment needs process liquid like recirculating digester medium
	Possible range for upscaling	50 – 1,500 m³/h raw biogas production	Multipliable and adaptable to other quantities
Data for assessment of economical added value, possible contribution to GHG-reduction and availability	Electricity demand (kWhel/Mg Substrate)	2 - 5 kWh_{el}/Mg for ultrasound; 2 - 5 Wh_{el}/Mg for Kombi-Hydrolysis	
	Heat demand (kWhth/Mg Substrate)	10 - 40 kWh_{th}/Mg substrate	Substrate heating to process temperature (approx. 40°C) in Kombi-Hydrolysis; demand is high with high amounts of slurry
	Chemical/additives demand (kg/h)	0	
	Demand of other substances (kg/h)	0	

	Full load hours (h/a)	8700	24/7 operation; maintenance once a year
	Dry matter content (range) (%)	3 - >60 % dm	Dry matter content of feedstock Input substrates are to be dissolved by recycled digester liquid
	Space requirement (m^2)	3 m^2 Wave-Box > 40 m^2 Kombi-Hydrolyses	For 50 - 300 m^3/h biogas production
	Staff requirement (excluding maintenance) (h/a)	0	Wave-Box doesn´t need any staff, Kombi-Hydrolysis needs personnel to be fed with solid substrates (instead of feeding a conventional feeder
	Specific capital costs (excluding project development, planning, permission and additional building costs) (€/Mg nominal capacity/h)	Please give exact specific cost if possible, if not please specify range. ☐ < 5.000 €/Mg/h ☒ 5.000 - 10.000 €/Mg/h ☐ 10.000 k€ - 15.000 €/Mg/h ☐ > 15.000 €/Mg/h	Investment based on 10 years lifetime for biogas plants up to 1 MW_{el} Including Wave-Box device and hydrolysis tank with complete technical equipment and control unit
	Maintenance costs (including spare parts, staff) (€/a or €/operating hour)	approx. 5,000 €/a	Remote monitoring included
	Production costs (€/Mg)	1,50 – 2,00 €/Mg	Capital, operating and maintenance Depending on yearly feeding rate
	Expected lifetime of unit (years)	10 - 15 years	Ultrasonic resonant units (sonotrodes) must be replaced earlier (included in spare part costs)

Flexibility	Types of substrate (solid and liquid)	Solids: Fibrous materials as grass silage, dung, manure, other organics after dissolving Liquids: Cattle and pig slurry, digestate, sewage sludge	
	Start-stop-flexibility	Yes	
	Part-load possibility	☐Yes, 10 % of full capacity ☐ No	
	Is self-maintenance of technology possible?	☒ Yes, 50 % of total maintenance hours per year that can be done by operator himself ☐ No	
	Necessity for adaptions of other parts of the plant	no	Only on demand of operator: integration into plant control system
	Advantages/disadvantages of technology	<u>Advantages</u>: 24h/7d operating, Different substrates, Possible adaption to substrate change, Low viscosity, Low maintenance costs, Low operating costs, Enhancing CH_4-content <u>Disadvantages</u>: Investment costs	
	Special application area of technology	Bad or normal operating biogas plants, with a wide field of substrates	