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

Anaerobic Digestion Technologies

Contact Information:

TECHNOLOGY/ EQUIPMENT SUPPLIER	*Name of institution:*	Applied Nanoparticles SL		
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	Date (of filling the TD):	15.05.2017		

Technology Description:

NAME OF TECHNOLOGY	BioGAS+
ASSIGNMENT OF TECHNOLOGY	Nanoparticulated iron based additive
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
TECHNOLOGY/EQUIPMENT AVAILABILITY	Research Amounts of Additive
PATENT RIGHTS	**YES**

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METHOD OF MAKING THE TECHNOLOGY AVAILABLE	*Licence selling*	**YES**
	Licence granting	**YES**
POSSIBLE END USERS OF TECHNOLOGY	*Please name end users/ contacts that should be invited to project workshops*	Organic waste managers, Anaerobic digester managers

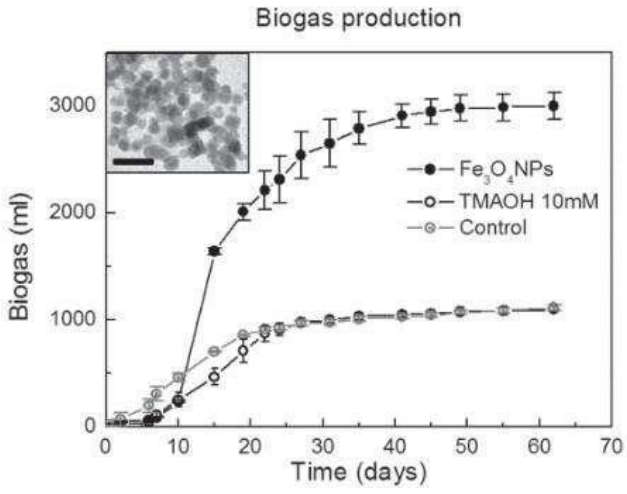
Description of the technology/equipment:

The Product - BioGAS+ by Applied Nanoparticles

BioGAS+ is the first ready to use additive based on safe and sustainable engineered iron-based nanoparticles directed to the optimization of anaerobic digestion processes which increases the production of biogas (a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen, mainly CO_2 and CH_4). Thus, the process that converts organic waste into raw matter for energy production is optimized by simply adding a small dose of iron (Fe) based nanoparticles (NPs) to either a large waste treatment reactor, a septic tank, or a homemade biodigester.

Technical Description

It is known that the addition of Fe ions to an anaerobic bacterial reactor can increase methane production, however introducing such ions can give rise to toxicity and excess reactivity. These problems are solved with BioGAS+ iron based nanoparticles: NPs can be designed to corrode and dissolve in a controlled manner, thereby providing a Fe optimized dosing source because of their denseness, chemical composition, crystal structure, nanometric size, and high reactivity. In conditions of anaerobic digestion small doses of mixed iron oxide NPs serve as a *catalyst* that stimulates bacteria metabolism and accelerates the production of biogas.



Differential advantages

Increase biogas and biomethane production: BioGAS+ is a disruptive technology because it obtains the highest ever-reported improvement of biogas production: triples the biogas yield with cellulose as feedstock in laboratory conditions - DIN-38414- and obtains over a 30% methane ratio increase in real industrial settings, with real feedstock and with optimal concentrations below the 1% (with respect to the Volatile Solids). Sucha methane production increase is far above any known technology aimed at increasing biogas production: many existing technologies approach this problem (i.e. pre-treatment of the biomass, thermalization of the waste, combination of feedstock and inoculums) but only obtain modest production increases. Moreover, many tend to be costly to implement since they usually require structural changes in the biogas production process. The unprecedented methane ratio increase is the most appealing advantage of BioGAS+, but it also offers additional differential advantages, including:

- Improved biomass to biomethane conversion efficiency.
- Better biogas composition (higher methane share).
- Higher waste degradation. An improvement of anaerobic digestion of biomass will lead to a less bioactive end-of-waste digestate, which is more appealing for composting and re-use.
- Acceleration of the digestion process. Reduction in retention / residential time and in the digestate fraction.
- Enrichment of the residual material (digestate) with iron ions to obtain by-products with increased economic value such as high quality fertilizers.
- Additive (it does not require any change in the biogas plant industrial process).
- As proved suitable for “difficult to digest” feedstock it enlarges available biomass feedstock previously discarded or recalcitrant organic matter. .
- Reduced AD plant energy consumption.
- Minimization of undesirable side effects in biogas plants such as the odours associated with HS and NH_3, thus reducing the cost of associated conditioning measures.

Patent

The Private Foundation Catalan Institute of Nanoscience and Nanotechnologies (ICN2), the Catalan Institute for Research and Advanced Studies (ICREA), and the Autonomous University of Barcelona (UAB) are the owners of *<<a method for increasing the production of biogas in anaerobic digestion processes of biodegradable material by adding nanoparticles iron oxide>>.* The Patent owners and Applied Nanoparticles SL have signed an Exclusive Licencing Agreement dated 21/07/2015. This method is protected in Europe by patent application 12707361.7.1352 Ref. P1923EP01/EP2683662 and in the USA under Patent US 9,416,373 B2 dated August 16th, 2016 BIOGAS PRODUCTION

AWARDS and MILESTONES:

2008. Grant Spanish Environmental Ministry. Nanoclean Up. The use and the effects of NPs in waste water treatments.

2010. Discovery of Magnetite NPs on Anaerobic Digestion.

2011. Patent deposited in the EU and US This method is being protected in Europe by patent application 12707361.7.1352 Ref. P1923EP01/EP2683662 and in the USA by patent application nr. 14/004.646 and publication nr. 2014/0017753. Priority Data: 11/03/2011

2011 Bill and Melinda Gates foundation - project award and funding.

2012-2013 Fundación Repsol Award Cathegory IDEA

2013 Applied Nanoparticles is created.

2014 Scientific Publication of the phenomena:

2013 Secretaria General Iberoamericana, 2nd Innovation Prize

2013 Patent made public 20/09/2013

2014-2016 Fundación Repsol Award Category INNOVATION 2014-2016

2015 MINECO bussines plan AWARD

2016 Industrial Production of BiogasPLUS reached and subcontracted

2017 First satisfactory results in continuous treatments in Pilot Plants.

2017 February COMPASS AWARD for Responsible Research and Innovation

2017 Summer. Direct Open Commercialization of BiogasPLUS Beta Version.

Technical Data:

Due to the nature of our product, an additive to anaerobic digesters, we have worked with a variety of substrates and digesters. Through direct collaboration with various AD-based departments and companies we have optimized the use of BioGAS+ (dosage, periodicity of addition, retention times...) to maximize biogas production for each of our future clients.

			Comments (e.g. which condition does the entered value correspond to?)
Technical efficiency	Methane content in biogas (%)	Up to 79%	Depending on substrate. Content i CH4 always higher when using our additive BioGAS+ than the control without adding it.
Capacity	Flow rate and type per substrate (Mg/h)	*	
	Biogas production rate (range) (Nm^3/h)	*	
	Possible range for upscaling	*	
Data for assessment of	Fermenter and biogas process technology	*	
	Electricity demand (kWh_{el}/Nm^3 biogas)	*	

economical added value, possible contribution to GHG-reduction and flexibility	Heat demand (kWhth/Nm³ biogas)	*	
	Chemical/additives demand (kg/h or kg/Nm³ biogas)	0.1-0.01% of VS	
	Demand of other substances (kg/h or kg/Nm³ biogas)	*	
	Temperature in fermenter (°C)	*	
	Pressure of biogas at exit of fermenter (bar $_{abs}$)	*	
	m³ fermenter volume used	*	
	Full load hours (h/a)	*	
	Hydraulic retention time (days)	*	
	Max. dry matter content (%)	*	
	Organic loading rate (kg VS/m³d)	*	
	Space requirement (m^2)	*	
	Staff requirement (without maintenance) (h/a)	*	
	Capital costs (€)	*	
	Maintenance costs (including spare parts, staff) (€/a or €/operating hour)	*	
	Production costs (€/Nm³ biogas)	*	
	Expected lifetime of unit (years)	*	
Flexibility	Types of substrate (solid and liquid)	Mostly tested on urban sludges and cellulose-rich substrate. Also tests on slaughterhouse waste water, manure, oil and fat residues have been performed.	

	Necessity for adaptions of other parts of the plant	Considered barrier free	Though a case by case (type of substrate and working regime) study of dosification and biogas increase potential is advisable
	Advantages/disadvantages of technology	Improved biomass to biomethane conversion efficiency. Better biogas composition (higher methane share). Higher waste degradation. An improvement of anaerobic digestion of biomass will lead to a less bioactive end-of-waste digestate, which is more appealing for composting and re-use. Acceleration of the digestion process. Reduction in retention / residential time[6] and in the digestate fraction. Enrichment of the residual material (digestate) with iron ions to obtain by-products with increased economic value such as high quality fertilizers. Additive (it does not require any change in the biogas plant industrial process). As proved suitable for "difficult to digest" feedstock it enlarges available biomass feedstock previously discarded or recalcitrant organic matter. . Reduced AD plant energy consumption. Minimization of undesirable side effects in biogas plants such as	

		the odours associated with HS and NH3, thus reducing the cost of associated conditioning measures.	
	Special application area of technology	Digesters (as additive)	

* As our product is an additive to “virtually” any already working digester, all these required values would vary for every digester/substrate/regime.