EU AGRO BIOGAS PROJECT

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ABSTRACT: EU-AGRO-BIOGAS is a European Biogas initiative to improve the yield of agricultural biogas plants in Europe, to optimise biogas technology and processes and to improve the efficiency in all parts of the production chain from feedstock to biogas utilisation.

Leading European research institutions and universities are cooperating with key industry partners in order to work towards sustainable biogas production in Europe. Fourteen partners from eight European countries are involved in the EU-AGRO-BIOGAS project that aims at the development and optimisation of the entire value chain – that ranges from the production of raw materials, the production and refining of biogas; to the utilisation of heat and electricity.

A online European Feedstock Database was developed from all participant countries from a substantial amount of data (more than 10 000 analyses). The online European Feedstock Database is designed as an open database where new data can always be added. It contains essential information on the quality of feedstock for fermentation including the methane production capacity. The online European Feedstock Database was built after the determination of biogas potentials of regionally available substrates and substrate mixtures. The set up of quality definitions for feedstock enables both the economic optimisation and optimisation of of energy output for different substrate mixtures for biogas production.

Field demonstrations of all technologies and methods developed in the course of EU-AGRO-BIOGAS project are the core element of the project. The EU-AGRO-BIOGAS project includes the following demonstration activities at commercial plant level: Innovative approaches of feeding technologies, monitoring, management and early warning system, newly developed sensors, approaches to improve the degree of efficiency of the fermentation steps (enzymes, micro-organisms, stirring technologies), a floating system which recovers a significant amount of methane from the digestate storage tank without requiring changes to the A.D. management chain.

A crucial task within the EU-AGRO-BIOGAS project is the economic and environmental assessment of the demonstration measures on selected medium- and large-scale biogas plants across Europe. The EU-AGRO-BIOGAS project started in January 2007 and will be completed in January 2010.

Keywords: *Biogas, Feedstock Database, Technological innovations, Environment, Economy, Sustainability*

1 AIM

EU-AGRO-BIOGAS aims at the development and optimisation of the entire value chain – to range from the production of raw materials, production and refining of biogas for heat and electricity. All developments and strategies are demonstrated in real life conditions. An efficient utilisation of raw materials is achieved through

- the definition of raw material quality,
- an increased input of secondary agrarian raw material components,
- by-products of the food and biofuels industry and
- optimised raw material mixtures (incl. pre-treatment).

The state of technology, management, economy and environmental effects is assessed through benchmarking on selected medium- and large-scale biogas plants across Europe. The improvement of biogas efficiency, conversion and utilisation (technical, economical, ecological) is shown by demonstrations on selected biogas plant across Europe. The energy efficiency is improved through optimised heat management. Demonstration activities (technical, economical, ecological) are benchmarked and recommendations for an efficient biogas production are developed and widely disseminated.

2 RESULTS

2.1 European Feedstock Database and EU - Methane Energy Valuation Model (MEVM) standard methodology

Based on intensive literature surveys by all project partners and lab-scale experiments of feedstock from all participant countries, a substantial amount of data was collected and the main aim, the development of the new and comprehensive online European Feedstock Database (http://daten.ktbl.de/euagrobiogas/) on feedstock for biogas plants, was fully achieved.

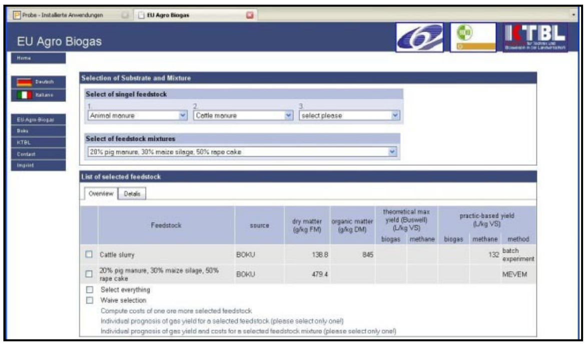

Figure 1: Europewide Online Feedstock Database

The online European Feedstock Database (Fig.1) is designed as an open database where new data can always be fed in. It contains essential information on the quality of feedstock utilizable for fermentation including their methane production capacity. The following feedstock groups are represented in the database: energy crops, animal manures, by-products of the food, feed, and biofuel industry and harvest residuals. The database contains information on feedstock, which are most important for European biogas production from a quantitative and qualitative point of view. The database depicts the existing variety of available feedstock in Europe. In the database, 667 data on biogas yield, 767 data on methane yield and 9,291 data on substrate analysis from energy crops, animal manures, agricultural residues, other waste materials and substrate mixtures are currently available.

Methane energy value models (MEVM) were developed for the prevailing feedstock of maize silage, sorghum silage, triticale silage, and sun flower silage. The same was done for feedstock mixtures containing remains from bio-refinery systems, agricultural residues and energy crops. The online European Feedstock Database allows an initial testing of biogas potentials of regionally available substrates and substrate mixtures. The set up of quality definitions for feedstock enables the economic and energetic optimisation of substrate mixtures for anaerobic digestion. Hence, the online European Feedstock Database is a basis for the planning of biogas plants and is organised as an expert database to support planners, consultants, plant operators, plant breeders and advisors of agricultural biogas plants.

2.2 Benchmarking, weak point analysis and early-warning system

A selection of commercial plants has provided information on the fermentation parameters, economics, monitoring instrumentation and plant schematics. These parameters were benchmarked and compared to identify weak points from a statistical perspective. Additional weak point analysis was provided by the plant operators. These information were used to define the needs of the early warning system and to highlight the demonstration activities. The constrictions of which parameters can be measured and those needed for process control were balanced and the means of process control and management of the biogas plant by software control were identified. The method involves the use of a soft-sensor, which is a means of using easily acquired data and mathematically constructing a more appropriate parameter. New means of process control have been identified that provide early warning of process failure and ultimately will lead to better biogas production.

A pilot scale system was used to investigate both, different sensors for fermentation monitoring and mathematical solutions to process control. The influence of different feedstock on biogas output, process control and monitoring is being investigated. Feedstock will include manure that is quickly digested and energy crops which are less easy to hydrolyse and may require different operational parameters. Our generic approach will enable adaptation to these needs. Successful mathematical models of process control are being progressively identified and validated.

2.3 Technological innovations in process optimisation

Tests and experiments at lab-scale and also at plant level have been accomplished to improve the degree of efficiency in producing biogas. The efforts concentrated on the optimisation of feedstock pre-treatment, the use of enzymes and new approaches in feeding technology.

Many plant operators in Europe use lingo-cellulose-rich raw materials such as solid manure, grass silage or similar feedstock as input in their biogas plants. In order to increase the availability of this feedstock for digestion, it is necessary to pretreat the material. A promising method could be the pretreatment with fungal enzymes, which will support the hydrolysis of the ligno-cellulose complex (Fig.2).

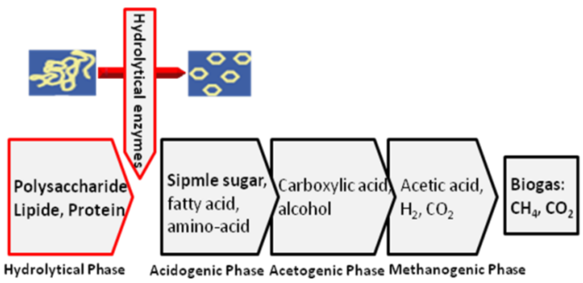

Figure 2: Support of hydrolytical segregation of polymers by fungal enzymes

Experiments at plant level have been conducted at the biogas plant of Rhinmilch GmbH, Fehrbellin, Germany, based on results of lab-scale experiments from Suárez Quiñones et al.. The focus of this experiment is an improved biogas production from given substrate (grass silage) and to enhance the activity of the fermentation process, to reduce formation of swimming layers and to decrease agitation power (Table I).

Table I: Data of biogas plant

Substrate amount	[m³/d]	183
Hydraulic retention time	[d]	33
Biogas production	[m³/d]	13 600
Methane content	[%]	54
Electricity production	[kWh/d]	32 400
Heat production	[kWh/d]	37 200

In a first step, both components have been mixed together by a fodder mixer to achieve a sufficient contact surface of the enzymes and the grass silage. Owing to the standards of the manufacturer, the enzymes-substrate-ratio was fixed to 1:25 referred to the content of volatile solids (VS) of the grass silage. After mixing both components, the enzymes require some time to develop the optimum effect. This latency time has been optimized in the lab scale experiments and depends on the temperature of the mixture (optimum: 37°C).

In the following, the pretreated substrate mixture was fed to the digester by a drag-belt conveyor. The effect of the pre-treatment will be evaluated within the EU-AGRO-BIOGAS project by measuring the biogas production and the power consumption of the agitation device. Additionally optical surveys of the swimming layer in the digester will be done.

Lab-scale experiments for the optimisation of feedstock mixtures, the pre-treatment of feedstock and the addition of additives have been performed and partly transformed to pilot-scale level to achieve further information. To avoid methane emissions from the digestate storage tank, a coverage system was developed and is already tested at pilot scale to upgrade tanks, which have not been build gas tight.

2.4 Transforming biogas into heat and power

Extensive R&D and pre-demonstration activities are performed to reach improvements in the field of biogas utilization with Combined Heat and Power Plants (CHP). New technologies, like the Organic Rankine Cycle (ORC), add on power plants, and optimized technologies for heat utilisation or life cycle cost reduction through adjusted gas qualities are developed, designed and pre-validated. The drying and removal of ammonia from biogas with an improved gas scrubber has already shown the significant impact of gas impurities to the availability and operating costs of a CHP. A new more sulphur resistant type of exhaust gas heat exchanger has been developed; the validation phase already started. On two other plants the validations of advanced heat utilization technologies, e.g. grain dryer, wood chips dryer or fermentation residue dryer, are carried out. Two guidelines and reports respectively, regarding the optimized CHP use in agricultural biogas plants and best practice and standard for using heat to feed the public network will be produced.

2.5 Demonstration at commercial plant level

Field demonstrations of all developed technologies and methods during the EU-AGRO-BIOGAS project are the core element of the project (Fig.3). The researchers and companies from all participant countries validate their inventions, ideas and products under real time and rough field conditions.

Demonstrations include innovative approaches of feeding technologies, a monitoring, management and early warning system and newly developed sensors at commercial biogas plant level, approaches to improve the degree of efficiency of the fermentation steps (enzymes, micro-organisms, stirring technologies), a floating system which recovers a significant amount of methane from the digestate storage tank without requiring changes to the A.D. management chain and measures to improve the degree of efficiency of the CHP and feeding into the heat network technologies.

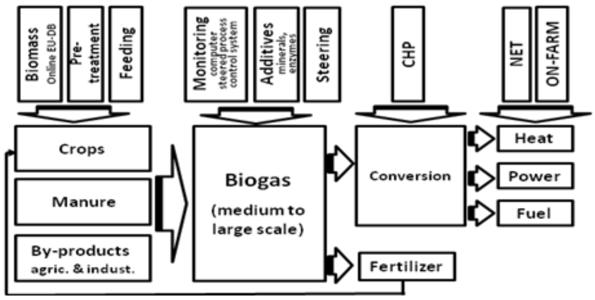

Figure 3: Demonstration activities along the supply chain – biogas life cycle

First results of a new feedstock mixture for high glycerol input, new systems for on-line measurements of process parameters (pH, conductivity, redox), NIR for process monitoring, thermo-chemical pre-treatment of feedstock, first validations of drying of poorly storable fodder for cows with belt dryers, improvements of the biogas quality with gas scrubber and demonstrating the ORC technology, are very promising in improving the biogas yield and efficiency at the selected commercial biogas plants.

2.6 Improvement of economic output and environment protection

A crucial task within the EU-AGRO-BIOGAS project is the economic and environmental assessment of the demonstration measures. Most of the demonstration actions have been launched recently and main results will be available at the end of the project in spring 2010.

GHG emissions and energy input/output-relations before and after implementation of the respective measure on existing biogas plants were compared among one another in a first step and later on set in relationship to the energy needed and GHG emitted when producing the corresponding amount of electric energy (and heat) from fossil resources [3].

The calculation model follows the general approach of life cycle assessment according to the ISO 14040 series using life cycle inventory data by ecoinvent (Swiss Centre for Life Cycle Inventories). The complete anaerobic treatment and biogas conversion process is taken into account, from the construction of the plant itself to feedstock production/provision and plant operation and finally to the application of the fermentation residues.

Preliminary results presented here have been done on basis of further calculations [3] and refer to two biogas plants in Austria (Steiermark) and northern Italy (Piemonte) with a connected power of approx. 1 MW each. Main feedstocks are energy crops and livestock manures. In the Austrian plant by-products from biodiesel production are used as well: initially only rapeseed cake in a small proportion, in the demonstration phase a large proportion of the energy crops was substituted by addition of glycerol [3].

2.7 CO_2eq reduction

At Plant A important reductions of GHG emissions could be achieved already at status quo level, i.e. by producing energy from biogas instead from fossil resources: taking into account only the replaced electricity GHG savings amounted to 69 % (0.24 kg CO_2eq per kWh_{el} instead of 0.78 kg from the Austrian fossil power mix). With the additional credit for the replacement of heating oil (0.31 kg CO_2eq/kWh_{th}) another 0.22 kg CO_2eq/kWh_{el} could be avoided – reflecting the high rate of heat utilization at Plant A and resulting in an overall reduction compared to fossil resources equivalent to 0.77 kg CO_2eq/kWh_{el} (75 %, Fig. 4).

At Plant B GHG reduction at status quo level was significantly lower; emissions compared to the Italian fossil power mix (0.76 kg CO_2eq per kWh_{el}) could be diminished by 38 %, corresponding to 0.48 kg CO_2eq per kWh_{el}. The additional effect of heat utilization accounts for only 0.06 CO_2eq per kWh_{el}. In total the replacement of fossil electricity and heat resulted in a reduction of GHG emissions equivalent to 0.34 MJ/kWh_{el} at Plant B (Fig. 4). Methane emissions from the open final storage at this plant amounted to 2.8 % of the total CH_4 production, but accounted for about 30 % of CO_2eq emissions of the overall biogas production and conversion process (data not shown).

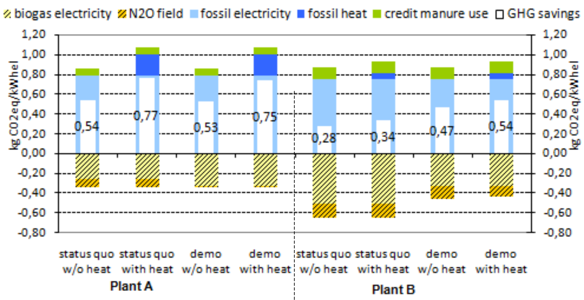

Figure 4: GHG emissions at two European biogas plants in comparison to energy production from fossil resources. Plant A: Austria; optimization measure ('demo'): substitution of energy crops by glycerol. Plant B: Italy; optimization measure: gas-proof coverage of final storage and use of residual methane [3].

Substitution of energy crops as main feedstock by glycerol at Plant A ('demo') resulted in a comparable reduction of GHG emissions compared to the status quo. Consequently, compared to fossil resources the use of glycerol could decrease GHG emissions by 74 % (electricity and heat; Fig. 4).

At the Italian Plant B recovering the residual methane could reduce GHG emissions from the biogas process by about 34 % to a level of 0.27 kg CO2eq/kWhel). In total GHG reduction amounted to 0.54 kg CO2eq/kWhel, equivalent to 55 % of the corresponding emissions from fossil resources (Fig. 4).

2.8 CO2eq reduction costs

The costs linked with the reduction of GHG emissions by replacing fossil resources with biogas amounted at status quo level at Plant A to about 381 €/t CO2eq when replacing only electricity, and to 182 €/t CO2eq when replacing both electricity and heat. At Plant B mitigation costs are 683 (electricity only) and 517 €/t CO2eq, respectively (Fig. 5).

Producing electricity and heat with biogas mainly from glycerol instead of energy crops ('demo') reduced the mitigation costs at the Austrian Plant A to 44 €/t CO2eq. In the Italian Plant B the mitigation cost were by 45 % lower after the installation of the gas-proof cover compared to status quo level; GHG mitigation costs compared to fossil resources amounted to about 307 €/t CO2eq (Fig. 5).

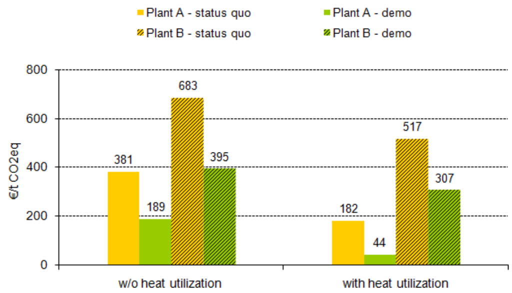

Figure 5: GHG mitigation costs for energy production from biogas compared to fossil resources at two European biogas plants. Plant A: Austria, optimization measure ('demo'): substitution of energy crops by glycerol. Plant B: Italy; optimization measure: gas-proof coverage of final storage and use of residual methane [3].

2.9 Reduction of energy input

Like for GHG emissions the use of biogas reduced the energy needed to produce electricity or heat. At Plant A the energy input decreased by 87 % at status quo level (1.9 MJ/kWhel instead of 14.8 MJ from fossil resources (Austrian fossil power mix: 11.6 MJ/kWhel; heating oil: 4.6 MJ/kWhth); data not shown). In the Italian farm this effect was less pronounced; energy input was reduced to 2.9 MJ/kWhel compared to 12.5 MJ/kWhel from fossil resources (77 % reduction (Italian fossil power mix: 11.8 MJ/kWhel); data not shown).

Use of glycerol instead of energy crops in Plant A ('demo') resulted in an overall reduction of energy input by 92 % to a level of 1.16 MJ/kWhel compared to the energy needed to produce the same amount of electricity and heat from fossil resources. Due to the small change in overall energy input linked to the installation of the foil cover there was almost no effect on the energy input/output relation at Plant B (2.8 MJ/kWhel compared to 2.9 MJ at status quo; data not shown).

3 CONCLUSIONS AND OUTLOOK

The EU-AGRO-BIOGAS project objective was to optimize the biogas process, beginning with optimized feedstock mixtures, pre-treatment of the feedstock and the addition of enzymes and develop a system for the automated process control. The efforts improve the possibility to control biogas production and increase the yield of methane. The efforts give the plant owner the possibility to control the process and to produce biogas at a higher level of efficiency while minimising greenhouse gas emissions. A crucial task within the EU-AGRO-BIOGAS project is the economic and environmental assessment of the demonstration measures.

Biogas as an energy source was shown to be effective at reducing GHG emissions compared to energy production from fossil resources. However, reductions achieved vary significantly depending on the conditions: one of the main factors for efficient GHG mitigation is the utilization of the heat produced in the conversion process, accounting for up to 20 % of the CO2eq credits for the replacement of fossil resources. Within this investigation, the importance of avoiding residual methane emissions during the storage of fermentation residues was outlined. Even with residual methane emissions of about 3 % the GHG reduction potential of biogas production is significantly reduced. Gas-proof covering of the final storage is therefore strongly recommended by experts, especially as the captured methane can be used in the CHP.

The use of other feedstocks e.g, glycerol from biodiesel production represents can increase biogas production and reduce GHG emissions at the same time.

CO2eq mitigation costs consequently vary according to the strategy followed at the plants. In the Austrian biogas plant the mitigation costs of about 70 €/t CO2eq when using glycerol which is within a range which is commonly regarded as economically sensible (50-100 €/t CO2eq. Significantly higher CO2eq mitigation costs at an Italian biogas plant were identified, caused by high residual methane emissions from the final storage and the comparably low rate of heat utilization.

All results of the project will be presented at the final conference "Biogas 09" on 26th November 2009 in Wels (Austria).

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4 LITERATURE

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