EU AGRO BIOGAS PROJECT

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1 THE EU AGRO BIOGAS PROJECT

EU AGRO BIOGAS aimed at the development and optimisation of the entire biogas value chain – to range from the production of raw materials, production and refining of biogas to the utilisation of heat and electricity. All developments and strategies were demonstrated and proofed at real life conditions. An efficient utilisation of raw materials was achieved through the definition of raw material quality, an increased input of secondary agrarian raw material components and by-products of the food and biofuel industry, and energy and economically optimised raw material mixtures (incl. pre-treatment). The state of technology, management, economy and environmental effects was assessed through benchmarking on selected medium- and large-scale biogas plants across Europe. The improvement of biogas efficiency, conversion and utilisation (technical, economical, ecological) was shown by demonstrations on selected biogas plant across Europe. Heat utilisation was improved through optimised management. Demonstration activities (technical, economical, ecological) were benchmarked and recommendations for an efficient biogas production were developed and widely disseminated.

2 RESULTS

2.1 European Feedstock Database and EU Methane Energy Value 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.

The online European Feedstock Database 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 feedstock 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 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. This information was 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 was investigated. Feedstock included manure that is quickly digested and energy crops which are less easy to hydrolyse and may require different operational parameters. The generic approach enabled adaptation to these needs. Successful mathematical models of process control were 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 focussed on the optimisation of feedstock pre-treatment, the use of enzymes and new approaches in feeding technology.

Many plant operators in Europe use ligno-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

Experiments at plant level were conducted at a biogas plant in Germany. The focus of this experiment was to achieve an improved biogas production from the given substrate grass silage and to enhance the activity of the fermentation process, to reduce formation of swimming layers and to decrease agitation power transforming biogas into heat and power.

Extensive R&D and pre-demonstration activities were 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), and optimized technologies for heat utilisation or life cycle cost reduction through adjusted gas qualities were 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 was developed. On two other plants the validations of advanced heat utilization technologies, e.g. grain dryer, wood chips dryer or fermentation residue dryer, were 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 were produced.

2.4 Demonstration at commercial plant level

Field demonstrations of all developed technologies and methods during the EU AGRO BIOGAS project were the core element of the project. The researchers and companies from all participant countries validated their inventions, ideas and products under real time and rough field conditions.

Demonstrations included 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 anaerobic digestion A.D. management chain and measures to improve the degree of efficiency of the CHP and feeding into the heat network technologies.

Results of a new feedstock mixture for high glycerol input, new systems for on-line measurements of process parameters (pH, conductivity, redox), near infrared reflectance (NIR) for process monitoring, thermo-chemical pre-treatment of feedstock, 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 at the selected commercial biogas plants.

The demonstration actions were done at 12 different commercial biogas plants from all over Europe. The idea was to show different innovative technologies and approaches along the life-cycle of biogas production and to scientifically proof their effectiveness. The aim of most biogas operators is to increase the biogas yield which means higher output in power and heat which then can be sold. All these measures have then shown the increase in revenues and reduction of costs.

2.5 Economic assessment – EcoGas tool and environmental assessment – footprint tool

Life cycle inventories of the demonstration plants were carried out, following the principles of life cycle assessment according to the ISO 14040 series, using mainly life cycle inventory data from the Swiss Centre for Life Cycle Inventories (ecoinvent). The complete anaerobic treatment and biogas conversion process was taken into account, from the construction of the plant itself to feedstock production and plant operation and finally to the application of the fermentation residues. The following key indicators were defined:

- greenhouse gas emissions
- GHG mitigation costs
- energy input:output relation.

GHG emissions and cumulative energy demand on the different plants were used on the one hand to compare electricity and heat provision from biogas to those one from fossil resources. The main objective within the framework of the project was to assess the effect of optimizing measures implemented at the demonstrations plants: The situation before (‘status quo’) and after (‘demo’) implementation of the respective measures were compared. Again, savings as compared to energy production from fossil resources were calculated for optimised conditions. Finally, GHG emissions were combined with the costs for electricity production calculated with EcoGas to obtain the GHG mitigation costs at the individual plants

The resulting GHG savings were within a range from 0.34 to 1.26 kg CO_{2eq}/kWh_{el}, with highest savings achieved when livestock manure was digested in an important share and at the same time a considerable amount of the produced heat was used (Figure 1). Residue plants appear to realise higher savings; due to the smaller number of energy crop plants investigated and the differences in plant concepts this finding has to be verified in the future.

Credits for fossil electricity vary between the countries as national references were used which reflect the country-individual composition of the electricity mix. For heat the differing credits are on one hand due to the same effect (different prevailing fossil heat sources) and on the other hand to the extent of heat utilization which was plant individual. Inter-country comparisons based on the figures shown here are therefore difficult, because fossil national references which are related to high emissions result in higher savings as the same plant would be allowed for in another country. The aim of EU AGRO BIOGAS was however to show the savings on the individual plants, therefore using the national references. Still, the final report will show GHG savings and mitigation costs on the demonstration plants based on a common reference.

GHG mitigation costs varied from 15 to 553 € per t CO_2eq. Only two of the investigated 12 plants reached a cost level below 100 €, which is regarded to be the limit of economically reasonable measures to save GHG emissions. Total GHG savings per year of the 12 demonstration plants compared to fossil energy provision add up to 53 700 t CO_2eq per year before implementation of the optimisation measures.

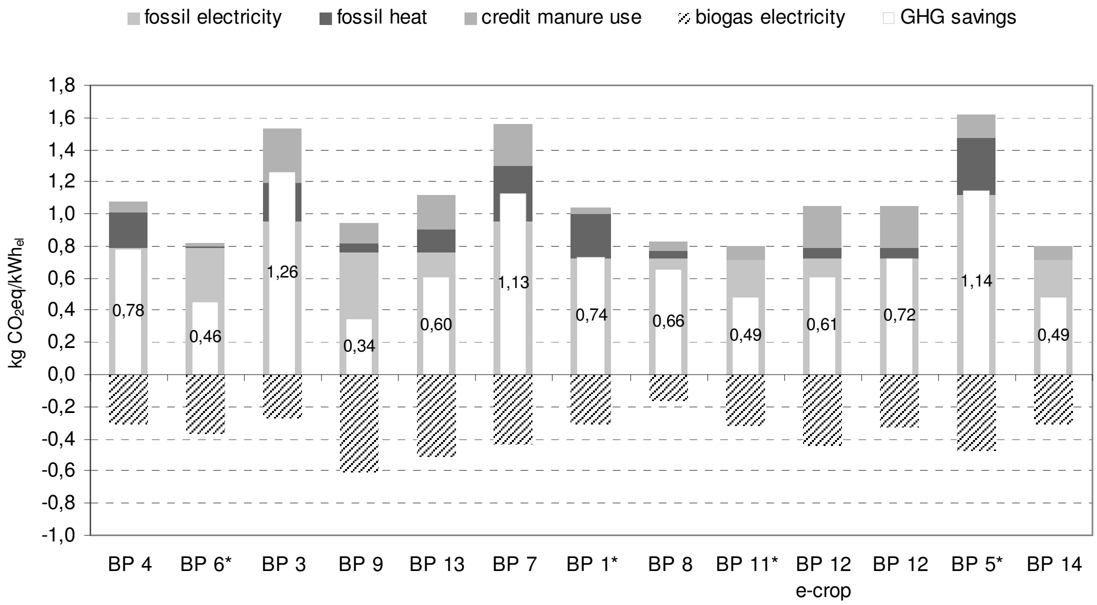

FIGURE 1 **Greenhouse gas balance and savings of electricity and heat production from biogas compared to fossil resources and GHG mitigation costs (€/t CO_{2eq}) – status quo**

3 CONCLUSIONS AND OUTLOOK

The EU AGRO BIOGAS project optimized the biogas process, beginning with optimized feedstock mixtures, pre-treatment of the feedstock and the addition of enzymes and developed a system for the automated process control. The efforts improve the possibility to control the biogas process and raise the yield of the produced methane. The efforts give the plant owner an improved 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 was the economic and environmental assessment of the demonstration measures.

Biogas as an energy source was shown to be an effective possibility for the reduction of GHG emissions compared to energy production from fossil resources. However, reductions achieved varied significantly. Electricity and heat from biogas can contribute to the substitution of fossil resources. On all investigated plants energy provision with biogas was associated with greenhouse gas and primary energy savings compared to the use of fossil resources. GHG mitigation costs were however in some cases elevated and did not meet the range of 50 to 100 €/t CO_{2eq}, which is regarded by experts to be economically reasonable. Implementation of various optimisation measures resulted in most cases in a considerable increase of GHG and energy savings and in significantly lower GHG mitigation costs. This illustrates the potential for optimisation of the economic as well as environmental performance of existing agricultural biogas plants.

The most efficient measures in this context are: enhanced heat utilisation, use of high shares of livestock manure, use of residues or waste, recovery of residual methane from digestate storage, improved efficiency of energy cropping and improved conversion efficiency in the digester. If these factors are taken into account GHG mitigation costs can reach a range which is regarded as economically justifiable.

The evaluation tools used and refined in the framework of EU AGRO BIOGAS have proven to be useful in assessing the contribution of individual biogas plants as well as plant concepts to GHG mitigation and primary energy savings. At the same time they can be used to evaluate and demonstrate the potential of optimisation measures in terms of economic as well as environmental efficiency. The EcoGas tool is designed in way that it can principally be used by any biogas plant operator, planner or consultant and it is already widely spread in Austrian regulatory authorities. The footprint tool is construed to analyse every type of biomass based renewable.

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