EU AGRO BIOGAS PROJECT

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Abstract

In this paper the most relevant results obtained during the 3-year EU-Agro-Biogas project, the European Biogas initiative to improve the yield of agricultural biogas plants, are presented. An online European Feedstock Database was developed from all participant countries, a substantial amount of data (more than 10,000 analyses) was generated and collected. All technologies and methods developed in course of EU-AGRO-BIOGAS were demonstrated and proofed at commercial plant level. EU-AGRO-BIOGAS included the following demonstration activities: 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 anaerobic digestion management chain. A crucial task within the EU-AGRO-BIOGAS project was the economic and environmental assessment of the demonstration measures on selected medium- and large-scale biogas plants across Europe.

Keywords: Biogas, Technological innovations, Sustainability

Introduction

In 2005, the European Commission adopted a Biomass Action Plan (CEC, 2005), which seek to promote the use of biomass in heating, electricity and transport. Biogas is heavily promoted as a key technology for the sustainable supply of renewable energy. It offers a high flexibility in substrates, thus avoiding food-feed competition (Dinuccio et al., 2010). In this context born EU-AGRO-BIOGAS project, the European biogas initiative to improve the yield of agricultural biogas plants (Amon et al., 2009). The project, founded by the European Union under the 6th Framework Programme, started in January 2007 and was finalised in January 2010. About 170 researchers and experts from 14 organizations and institutions in 8 EU countries (Austria, Germany, UK, Denmark, Italy, Poland, the Netherlands and the Czech Republic) were involved. Specific objectives of the EU-AGRO-BIOGAS project were:

▪set up a European online substrate atlas-database compiling the currently available information of feedstock for biogas production and standardised methane energy valuation model (MEVM)

▪to optimise the biogas production through a demonstration of an innovative feeding technology to bring in the substrate or mixtures into the agricultural biogas plant

▪to monitor, identify and benchmark the main influence factors during the technological process in agricultural biogas plants based on already available data and newly monitored medium and large agricultural biogas plants

▪to test, implement and demonstrate a newly developed monitoring, management and early-warning system for agricultural biogas plants and new and innovative technological solutions under full-scale operating conditions in agricultural biogas plants

▪to optimise and guarantee quality and safety of digested material

▪to improve, optimise and demonstrate several selected conversion technologies which will lead to an improvement of the degree of efficiency (CHP, heat utilisation)

▪to reduce the investment and operational costs of medium and large (500-1000 kWhel) agricultural biogas plants of about 20 to 30%

▪to disseminate and present the demonstration projects to planners, investors and farmers as potential users and to provide inputs for the future development of energy policy and legislation

To achieve such objectives 16 biogas plants across Europe were selected (Fig. 1) and monitored.

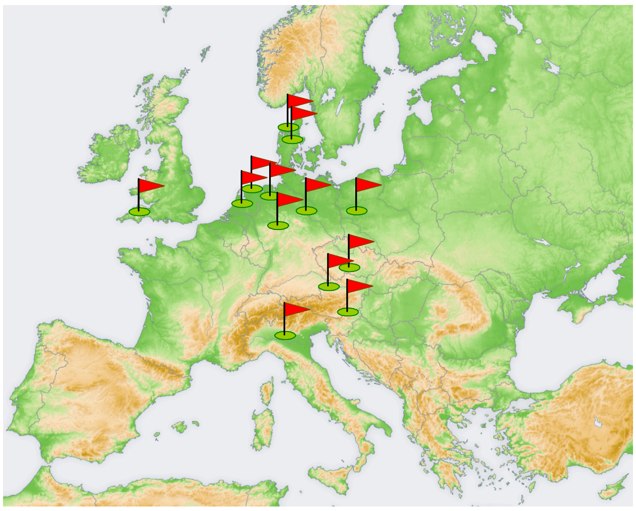

Fig. 1 – Geographic allocation of the selected biogas plants.

Results

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

Based on intensive investigation activity on the biomasses used to feed the selected biogas plants by all project partners and lab-scale experiments of feedstock from all participant countries, a substantial amount of data was collected and the development of the online European Feedstock Database (http://daten.ktbl.de/euagrobiogas/) (Fig. 2) on feedstock for biogas plants, was fully achieved.

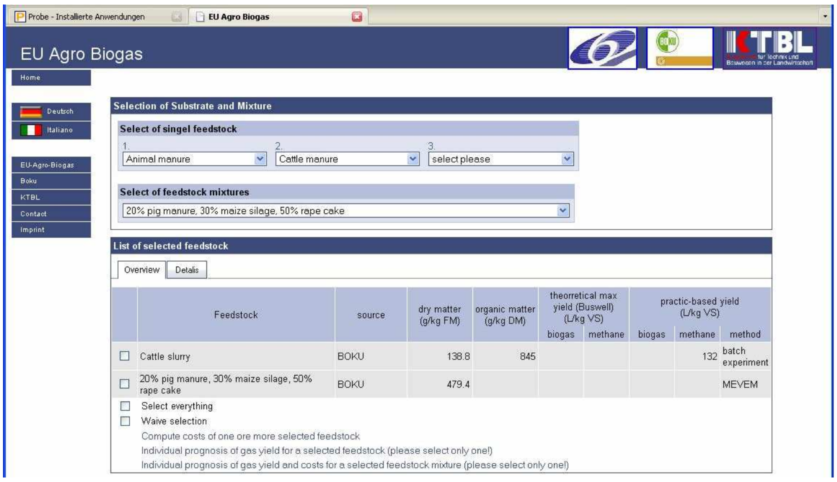

Fig. 2 – The online European Feedstock Database (http://daten.ktbl.de/euagrobiogas/).

The online European Feedstock Database is designed as an open database where new data can always be fed in. The database depicts the existing variety of available feedstock in Europe with 1,888 datasets for single feedstocks and 39 datasets for mixtures (Fig. 3).

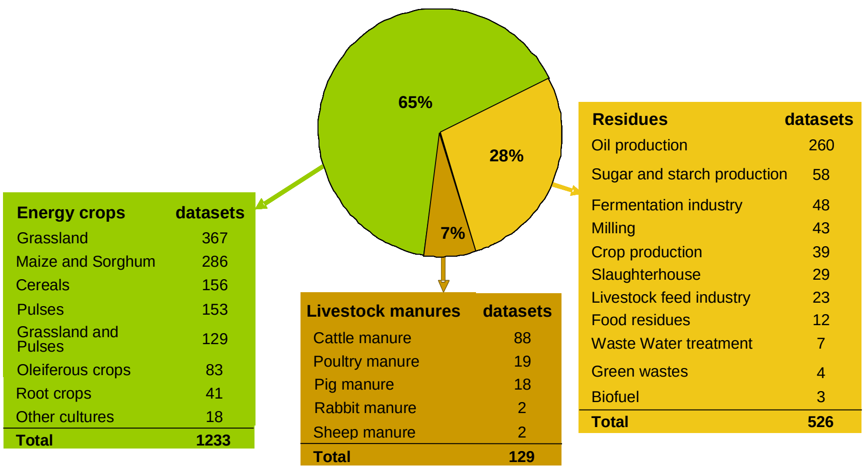

Fig. 3 – Feedstock types in the European Feedstock Database.

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: 667 data on biogas yield, 767 data on methane yield and 11,000 data on substrate analysis (e.g., pH, dry matter, crude protein, crude fibre, cellulose, hemi-cellulose, starch, sugar, lignin, crude fat and ash) from energy crops, animal manures, agricultural residues, other waste materials and substrate mixtures are currently available. In addition, the database contains information about feedstock production (e.g. energy crops: ripening stage, harvesting time, conservation method) and information about lab-method of fermentation experiments. 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, consulters, plant operators, plant breeders and advisors of agricultural biogas plants.

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. The key parameters to be monitored to prevent methanogenesis failure, were identified. The influence of different feedstock on biogas output, process control and monitoring were investigated. Feedstock included manure that is quickly digested and energy crops which are less easy to hydrolyse and may require different operational parameters. Successful mathematical models of process control were progressively identified and validated. 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. These information were used to develop a real time process monitoring (early warning system - Fig. 4). 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.

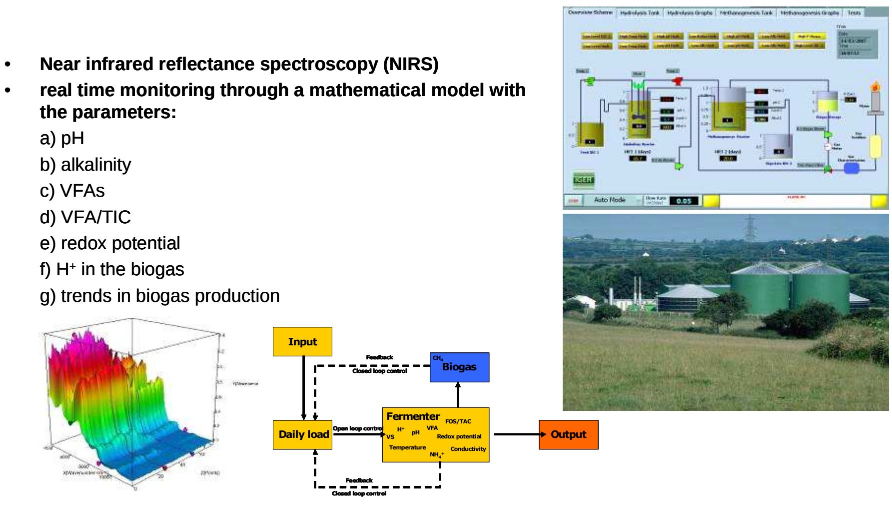

Fig. 4 – Schematic of the early-warning system.

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. Lab-scale experiments for the optimisation of feedstock mixtures, the pre-treatment (extreme thermophilic, steam-explosion, pressure cooking, ultrasonication, bio-extrudation) of feedstock and the addition of additives have been performed and partly transformed to pilot-scale level to achieve further information. The most appropriate pre-treatment methods under technical and economical pint of view were identified. To optimise the feedstock feeding at biogas plants, a new feeding and mixing system (QuickMix) (Fig. 5) was developed.

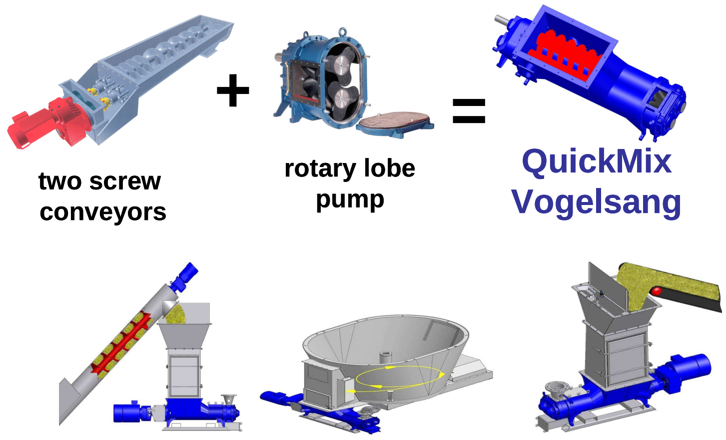

Fig. 5 – The QuickMix system.

The QuickMix system combines the advantages of traditional screw conveyor with rotary lobe pump. The advantages of the QuickMix system include: ability to handle a wide range of co-ferments, reduced energy consumption (up to -42%) for mixing and crust formation in the fermenter, higher biogas yield (up to +15%) and therefore higher efficiency compared to tradition feedstock feeding systems.
To recovery the residual biogas from digestate and to avoid polluting gas emissions from the digestate storage tank, an innovative floating cover system (Fig. 6) was developed and tested at pilot and full scale. The floating coverage can move upwards and downwards, jointly with the digestate surface during loading and unloading operations, without creating pressure and depressure conditions within the storage tank.

Fig. 6 – The floating cover system of the digestate storage tanks.

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, add on power plants, 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 showed 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 biogas plants the validations of advanced heat utilization technologies, e.g. grain dryer, wood chips dryer or fermentation residue dryer, were carried out. Two guidelines/reports regarding the optimized CHP use in agricultural biogas plants and best practice and standard for using heat to feed the public network were produced.

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 validate there inventions, ideas and products under real time and 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 management chain and measures to improve the degree of efficiency of the CHP and feeding into the heat network technologies.

Improvement of economic output and environment protection

A crucial task within the EU-AGRO-BIOGAS project was the economic and environmental assessment of the demonstration measures. The following indicators were used:

• energy balance

• emission of CO_2 equivalents and CO_2eq mitigation costs.

An existing tool (ecologic footprint tool) used for the calculation of these parameters was adapted for the requirements of the project, while for the economic part a specific software (EcoGas – Fig. 7)) was developed.

Fig. 7 – Starting page of the EcoGas software.

The economic and environmental impact of the demonstrated activities were clearly lined-out and assessed against the biogas plant status quo – comprising the whole biogas production process from feedstock provision (esp. cultivation of energy crops) to the feed-in to public power or heat supply systems. The results of the assessment will serve as a decision support for biogas planners and consultancy, plant operators as well as regulatory public bodies. The assessment will provide easily available sound economic and ecologic information (costs, benefits, potential side-effects) on a range of different optimisation measures. Both assessment tools (ecologic footprint tool, ECOGAS tool) were designed in an open and flexible way so that the whole range of biogas plants can be depicted and assessed in the future – independent of feedstock, technical equipment, process solutions etc. Consequently, an evaluation of new, innovative approaches at plant level will be possible during the planning process. Together with the online European Feedstock Database this will substantially improve planning security and thus provide an important decision support to the biogas community as a whole.

Conclusions and outlook

The results obtained during the 3-year EU-Agro-Biogas project highlighted the potential of anaerobic digestion technology to produce biogas at a higher level of efficiency while minimising greenhouse gas emissions. First 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 spectotroscopy (NIRS) 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, a floating cover system to recovery the residual biogas from digestate and to avoid polluting gas emissions from the digestate storage tanks, are very promising in improving the biogas yield at the commercial biogas plants.

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