PROBIOGAS

Madsen, Michael; Al Seadi, Teodorita; Hjort-Gregersen, Kurt; Christensen, Johannes; Nielsen, Lars Henrik; Møller, Henrik B.; Sommer, Sven G.; Birkmose, Torkild Søndergaard; Couturier, Christian; Zafiris, Christos; van Asselt, Bert; Mata-Álvarez, Joan; Heslop, Vicky; Rabier, Fabienne; Warnant, Gaëlle

Published in:
PROBIOGAS - Publishable Final Report

Publication date:
2007

Document Version
Publisher's PDF, also known as Version of record

Intelligent Energy Europe

PROBIOGAS

Promotion of Biogas for Electricity and Heat Production in EU-Countries. Economic and Environmental Benefits of Biogas

Project period: 01.01.2005-30.06.2007
Contract: EIE/04/117/S07.38588

PUBLISHABLE FINAL REPORT

Period covered: 01/01/05 – 30/06/07

Project co-ordinator:
University of Southern Denmark
Bioenergy Department
Esbjerg, Denmark

Supported by the European Commission under the **Intelligent Energy - Europe** Programme

SUSTAINABLE ENERGY EUROPE 2005-2008

PROBIOGAS

Promotion of Biogas for Electricity and Heat Production in EU- Countries
Economic and Environmental Benefits of Biogas from Centralised Co-digestion

Project period: 01.01.2005-30.06.2007
Contract: EIE/04/117/S07.38588

PUBLISHABLE FINAL REPORT

Project co-ordinator:
University of Southern Denmark
Department of Bioenergy
Esbjerg, Denmark

Colophon

Authors
Teodorita Al Seadi, Kurt Hjort-Gregersen, Johannes Christensen, Lars Henrik Nielsen, Henrik B. Møller, Sven G. Sommer, Torkild Søndergaard Birkmose, Christian Couturier, Christos Zafiris, Bert van Asselt, Joan Mata-Álvarez, Vicky Heslop, Fabienne Rabier, Gaëlle Warnant, and Michael Madsen

Editing
M.Sc. Teodorita Al Seadi
University of Southern Denmark, Department of Bioenergy

Proof reading and layout
Stud. mag. Catrineda Al Seadi, stud. M.Sc. Eng. Sidsel Nørrelykke Steffensen, stud. M.Sc. Eng. Sebastian Buch Antonsen, and M.Sc. Michael Madsen
University of Southern Denmark, Department of Bioenergy

Cover made by
Stud. mag. Catrineda Al Seadi
University of Southern Denmark, Department of Bioenergy

Date for completion of this report: 24th of August 2007

Acknowledgements
This report is based on contributions and the results obtained by the partners of the PROBIOGAS project. All the people involved in this project have our warmest gratitude for their contribution to the overall project work and activities and for their contribution to this report.

Teodorita Al Seadi
Editor and Coordinator of the PROBIOGAS project

TABLE OF CONTENT

1. Executive summary

Biogas is one of the cheapest ways of reducing the emissions of green house gases from agriculture, energy and the transport sectors. For this reason, the interest in promoting the biogas technologies is increasing in Europe. The PROBIOGAS project aims to assess and quantify the environmental and economic potential of biogas from anaerobic digestion by applying the results of two decades of biogas research in Denmark to six concrete case studies in selected European countries, where biogas technologies are not very developed. The main work consists of collecting data and carrying out environmental and economic costs and benefits assessments of centralised co-digestion in each one of the selected case studies. In parallel, the various target groups of the project are interactively involved in the project work and in the dissemination of results. The project activities and results were disseminated to the project target groups and to the overall European level throughout many levels of dissemination activities carried out by the coordinator and by each partner. A final European Biogas workshop was organised at the end of the project period in Esbjerg, Denmark presenting the main results of this project to a large international audience. The project results will be further used to raise awareness and to prove that biogas is economically and environmentally beneficial to local citizens and to society as a whole.

The most important activities carried out during the whole project period are listed below:

- Kick-off meeting in Billund, Denmark
- Interim meeting in Brussels, Belgium
- Final meeting in Esbjerg, Denmark
- Launching and up-dating the PROBIOGAS web page, hosted by **www.sdu.dk/bio**. The PROBIOGAS web page will be active until 30th of June 2009
- Selection and description of the case study region for assessment in each one of the six partner countries (France, Greece, Belgium, Spain, the Netherlands, and Ireland)
- Establishing the project Target Group Network in each one of the participating countries
- Organisation and carrying out six introductory workshops in the participating countries
- Elaboration of data templates and collection of data for the case study assessments
- Elaboration of a case study assessment report for each one of the six selected case studies and translation in national languages
- Elaboration of the final generic assessment report
- Organisation of national and international dissemination activities during the whole project period
- Organisation of the European Biogas Workshop and study tour "The Future of Biogas in Europe-III" in Esbjerg, Denmark, of which the main part was dedicated to PROBIOGAS project results
- Publishing the workshop proceeding report
- Releasing three project newsletters
- Elaboration and dissemination of project leaflet in English, French, Greek, Dutch and Spanish
- Holding working meetings with the assessment experts in Denmark
- Establishing contacts and collaboration with other similar projects
- Submitting three progress reports, an interim and a final report

During the project period, strong links have been made with other similar projects in Europe and with organisations working with similar topics, so an exchange of ideas will be made and discussions will be held as to how to continue these beyond the life of the project – particularly in relation to the development towards an implementation step in the partner countries, but also in the direction of carrying similar assessments for other case studies.

The PROBIOGAS project reached its final target and was closed, according to the schedule, the 30 June 2007. It is expected that the results of the project will be further disseminated by national partners and used to clarify the incentives and the barriers for each case study and will establish a platform for the initiation of future policy initiatives for the development of biogas. The partners involved will keep in touch with their target groups, in order to stimulate the interest and the involvement of the regional target group networks towards a decision to establish a co-digestion plant in that region.

The assessment of the economic, environmental and energy aspects of the biogas production by centralised co-digestion (CAD) is made using data collected from a real potential CAD situation. However, because the situation is not a live project, but only a potential one, it is called a hypothetical CAD. Because the assessment is based on models developed under Danish circumstances, the results can not be regarded as an adequate feasibility study ready for decision.
If a project was to be developed in this situation then a full feasibility study should be undertaken. The data in this document could be utilised to inform that feasibility study.

The results of the study only provide a snapshot in time. If any one of the parameters that were used in the assessment were to change, then the results would vary, often significantly, even with only a small change in the parameter. Also only some of the socio-economic benefits have been calculated, because reliable assessment data is not available for the benefits not included. However, experience shows that nearly all of the effects not assessed are beneficial.

Although calculations are based on real data collected some aspects have been estimated using Danish preconditions: costs of investments, technology used in the plant, reduction of nitrogen leakage. The results have to be used carefully knowing the specifics preconditions used for the study and not as constant figures that could be transposed directly to other studies.
For more information about the results you are invited to contact the national partner or one of the persons in charge with the respective work (see chap. 3 Promoters and target groups)

More information about the project and the produced deliverables and materials are now available at **http://websrv5.sdu.dk/bio/Probiogas/sub/home.htm**.

2. What is PROBIOGAS?

PROBIOGAS is the acronym of Promotion of Biogas for Electricity and Heat Production in EU- Countries - Economic and Environmental Benefits of Biogas from Centralised Co-digestion. As the name says, the project aims to promote biogas technologies in EU countries, by highlighting the benefits of the centralised co-digestion technology.

The Danish concept of centralised co-digestion of animal manure and other suitable organic substrates is a multifunctional concept, providing quantifiable environmental and economic benefits for agriculture, food industries, energy sector and the overall society and an effective tool in reducing green house gas emissions. This was documented by a research report published by the Danish Research Institute of Food Economics in 2002 (Report no 136: Socio-economic analysis of centralised biogas plants). It was for the first time that a range of quantified and monetised externalities from biogas production were assessed and the socio-economic effects and incentives for establishing and operating a centralised biogas plant were highlighted.

The European demand for the above mentioned results is essentially the background for this project and represents the argument for the formation of the PROBIOGAS partnership. There is a need for such assessments to be carried out for other cases in Europe, as their potential of offering incentives for the development of biogas technologies is obvious.

The main objective of PROBIOGAS was to assess and quantify the environmental effects and the economic and socio-economic potential of biogas from centralised co-digestion in selected case study regions in six European countries, where biogas technologies are not developed. The assessment work applied a method developed throughout two decades of biogas research in Denmark.

Apart from a core of Danish biogas experts, the PROBIOGAS partners were from six European countries where biogas technologies are not developed: France, Greece, Spain, the Netherlands, Ireland and Belgium.

A case study for assessment was selected in each country. The selected case studies are actually regions with intensive animal production, which could benefit from implementing and developing anaerobic digestion technologies for the treatment of manure. It was estimated that these regions have a potential of centralised biogas production, which has not yet been realised due to a range of non-technical barriers. The assessment of the non-technical barriers
was another objective of this project. The whole action was based on the interaction between national partners, the project target groups and a core of Danish experts who carried out the assessment work.

The PROBIOGAS project was co-financed by EC/IEEA, throughout the ALTENER Programme with a total budget of 887.178 Euro, of which 50% was EC contribution.

This report contains information concerning the project concept and the selected case studies, illustrating some of the most significant activities and results gathered during the whole project period (01.01.2005 - 30.06.2007) and trying to estimate the impact of the PROBIOGAS project in the involved countries.

3. Promoters and target groups

The promoters of the project are: University of Southern Denmark- Bioenergy Department, Denmark, Danish Research Institute of Food Economics, Denmark, Risoe National Laboratory, Denmark, Danish Institute of Agricultural Sciences, Denmark, Danish Agricultural Advisory Centre, Association Solagro, France, University of Barcelona, Spain, Centre for Renewable Energy Sources, Greece, Methanogen Ltd., Ireland, SenterNovem, the Netherlands, Agricultural Research Centre of Wallonia, Belgium. A complete list of the persons involved can be found on page 10 in this report.

The accomplishment of a biogas project is very complicated and involves a range of main actors, persons, organisations and authorities. It is important that all players in a biogas project realise the potential in the project for their specific interests and interact with a variety of members of the target group: policy makers and local authorities, farmers, and farmers associations, biogas specialists, energy and energy trade companies, energy and environmental agencies, food processing industries etc.

For the reasons mentioned before, a target group network was formed for each case study region, at the beginning of the project. The project team interacted with the specific target groups from the early stage of the project and an introductory workshop was organised in each participant country. That the target group networks are the main target for dissemination of project results and it is hoped that they will form the organisational structure necessary for future project generation in the respective regions.

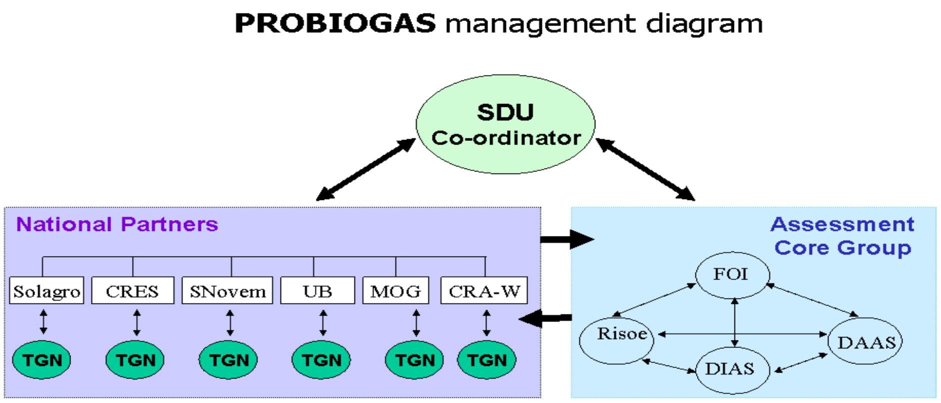


Figure 3.1 Management diagram of PROBIOGAS

The role of the members of the target groups is different from case to case. In countries where removal of non-technical barriers and legal changes are crucial for the development of biogas, policy makers are an important target group. The local and regional authorities will have to approve biogas projects and it is important that they realise that biogas production from anaerobic digestion improves environment in several ways. The energy trade companies should realise the potential for new market options of the renewable electricity and heat. The energy agencies formulate national energy strategies, so it is important that they understand the multifunctional nature of co-digestion and that it is a competitive tool in GHG reduction and environmental improvement. The animal farmers are the suppliers of manure substrate for anaerobic digestion, so it is important that they realise that there is a potential for economic benefits from improved manure management, cost savings in fertiliser purchase, less manure transport. This is also valid for farmers' advisory services and organisations. The food processing industries can be motivated to supply organic waste to the biogas plants, as an environmental and economical favourable way of recycling of organic waste. This must also be supported by environmental legislation, which should promote recycling of organic matter.

Figure 3.2. PROBIOGAS interim meeting in Brussels, February 2006

Figure 3.3. Final PROBIOGAS final project meeting in Esbjerg, June 2007

Project Coordinator

1. SDU - University of Southern Denmark

Teodorita Al Seadi

Department of Bioenergy
Niels Bohrs Vej 9-10, DK-6700 Esbjerg, Denmark
Tel: (+45) 6550 4168
Fax: (+45) 6550 1091
E-mail: tas@bio.sdu.dk

Project Partners

Assessment Core Group

2. FOI - Danish Research Institute of Food Economics

Kurt Hjort-Gregersen

Rolighedsvej 25, DK-1958 Frederiksberg C, Denmark
Tel: (+45) 65504167
Fax: (+45) 65501091
E-mail: khg@bio.sdu.dk

3. RISOE - Risoe National Laboratory

Lars Henrik Nielsen

Frederiksborgvej 399, DK-4000 Roskilde, Denmark
Tel: (+45) 46775110
Fax (+45) 467751 99
E-mail: l.h.nielsen@risoe.dk

4. DIAS - Danish Institute of Agricultural Sciences

Sven G. Sommer

Dept. of Agricultural Engineering
P.O. Box 536, DK-8700 Horsens, Denmark
Phone: (+45) 89993063, fax: (+45) 76296100
E-mail: SvenG.Sommer@agrsci.dk

Henrik B. Møller

Phone: (+45) 89993043
E-mail: HenrikB.Moller@agrsci.dk

5. DAAS - Danish Agricultural Advisory Service

Torkild S. Birkmose

Udkærsvej 15, Skejby, DK-8200 Århus N, Denmark
Tel: (+45) 87405432
Mobile: (+45) 30921707
Fax: (+45) 87405090
E-mail: tsb@landscentret.dk

National Partners

6. SOLAGRO

Christian Couturier

75 Voie du TOEC - 31076 Toulouse cédex 3, France
Tel : (+33) 567696969
Fax (+33) 567696900
E-mail: christian.couturier@solagro.asso.fr

7. CRES - Center for Renewable Energy Sources

Christos Zafiris

19th km Marathonos Ave, 190 09 Pikermi, Greece
Tel: (+30) 2106603300, -261
Fax: (+30) 2106603301
E-mail: czafir@cres.gr

8. SenterNovem

Bert van Asselt

P.O. Box 8242; 3503 RE Utrecht, The Netherlands
Tel: (+31) 302393414
Fax: (+31) 302316491
E-mail: b.van.asselt@senternovem.nl

9. UB - University of Barcelona

Joan Mata-Álvarez

Department of Chemical Engineering
Martí i Franquès 1, 6th floor, E-08028 Barcelona, Spain
Tel. (+34) 934021305
Fax (+34) 934021291
E-mail: jmata@ub.edu

10. MOG - Methanogen Ltd.

Vicky Heslop

Tooracuragh, Ballymacarbry, c/o Waterford, Ireland
Tel: (+35) 35236304
Fax: (+35) 35236304
E-mail: vickyheslop@eircom.net

11. CRA-W - Agricultural Research Centre

Fabienne Rabier and **Gaëlle Warnant**

Agricultural Engineering Department, ValBiom Asbl
Chaussée de Namur, 146 B-5030 Gembloux, Belgium
Tel : (+32) (0) 81627169
Mobile: (+32) (0) 498634881
E-mail: rabier@cra.wallonie.be
E-mail: warnant@cra.wallonie.be

4. Why PROBIOGAS?

Many biogas projects are abandoned at an early stage as the potential investors and promoters are often unaware of the business opportunities and the economic and environmental benefits associated with biogas systems. The lack of awareness would not allow them to undertake the assessments required, to negotiate appropriate agreements and to obtain the necessary financing.

Over the last 30 years considerable efforts were carried out in Denmark to develop cost efficient biogas production systems. The development was initiated by the oil crises in the early 1970'ies when a number of small-scale pilot plants were established. In the early 1980'ies the centralised co-digestion plant developed, proving that a larger plant, receiving manure and organic wastes from several farms, performs significantly better than individual farm plants.

In the beginning, the predominant interest in biogas from anaerobic digestion was driven by the production of renewable energy. Later on, as awareness about the environmental impacts of livestock production and manure handling increased and national regulations in this field became significantly restrictive, animal farmers faced mandatory requirements of storage capacity for their manure and restrictions concerning the amounts and the seasons for manure application as fertiliser. They could get important economic support from the government, to help them comply with the new regulations, but the support was conditioned of supplying the manure to a co-digestion biogas plant. This way, the Danish government created a favourable framework, where the farmers became the driving force for the development of biogas from centralised co-digestion, in the decade 1985-95.

Centralised co-digestion of manure and suitable organic wastes is today a mature technology, economically sustainable and a cost efficient tool for reducing the emissions of green house gases and environmental improvement. The technology provides economic and environmental benefits by renewable electricity and heat production, improved manure management and increased waste recycling. It reduces the nutrient losses to water systems, the emissions of methane and nitrous oxide and the odours and flies nuisance from manure storage and application, increasing also the veterinary safety by sanitation. This was documented by the Report no 136 Socio-economic analysis of centralised biogas plants, published by Danish Research Institute of Food Economics in 2002. For the first time, a range of externalities from biogas from anaerobic co-digestion were quantified and monetised, revealing the environmental, economic and socio-economic benefits for the society. This kind of documentation is needed in many other EU countries, where the biogas technologies are not developed and it is essentially the background for the PROBIOGAS project work.

The experience from Denmark proves that biogas from centralised co-digestion is a multifunctional concept, providing quantifiable environmental and economic benefits for agriculture, industry, energy and the overall society and could be an important tool in controlling GHG emissions from agriculture and the waste management. Quantification of the potential environmental and socio-economic effects of centralised co-digestion in regions with environmental problems caused by intensive agriculture and no incentives for biogas production reveals the benefits that could be achieved by implementing this technology and highlights some important non-technical barriers, which must be removed in order to make biogas from co-digestion a lucrative activity.

The work of the project is based on the results of the research carried out in 2002 by a team of Danish researchers, where environmental and economic costs and benefits of the centralised biogas technology, derived advantages and drawbacks are quantified and monetised using a welfare-economic methodology. The main objective of the project is to assess these aspects for selected case study regions in six European countries, where biogas technologies are not developed and to disseminate the obtained results to the target groups and to the overall European level.

The project activities and results are aimed to highlight the incentives and the barriers for the development of biogas from centralised co-digestion in each one of the assessed case studies. The dissemination of the project results should raise awareness about biogas technologies, as a socio-economic and environmental beneficial activity that can contribute to achieving national environmental targets.

5. What is centralised co-digestion?

Basic principles of anaerobic digestion

By definition, anaerobic digestion is a microbiological process during which organic matter is decomposed into biogas and microbial biomass in the absence of air. Biogas is a mixture of methane (CH_4) and carbon dioxide (CO_2). Hydrogen sulphide, H_2S, water, H_2O, and numerous trace gasses are present in smaller amounts. The typical composition of biogas is listed in Table 5.1

Table 5.1. Composition of biogas

Component	CH_4	CO_2	H_2S	NH_3	H_2O
Concentration	55-70 vol-%	30-45 vol-%	~500 ppm	~100 ppm	saturated

Anaerobic digestion is a complex process that involves interaction between many different microorganisms, so-called *consortia*. Each consortium lives optimally at a given set of chemical and physical conditions.

A number of macro- and micronutrients are required in order to facilitate the biological conversion and growth processes. Ten macronutrients; namely carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorous, calcium, potassium, iron, and magnesium, should be present in concentrations exceeding 10^{-4} M. Among important micronutrients, nickel and cobalt are found. The micronutrients should be present in concentrations below 10^{-4} M.

The relationship between carbon and nitrogen, referred to as the C/N ratio, has to be balanced to secure a stabile process. The optimal value is around 25. For instance, feedstocks with low C/N rations, i.e. having high nitrogen content, have to be counterbalanced by feedstocks having high C/N ratios. Feedstocks with high nitrogen content include pig manure, poultry manure, and stomach content from abattoirs. Feedstocks rich in carbon are crops, straw and grasses, and silages. Generally, all nutrients can be become inhibitory, if they are present in too high concentrations. Hence, it is important that the biogas reactor is balanced with respect to all of the nutrients.

Compounds that exert toxic effects include heavy metals and organic micropollutants. However, exposed to the toxic compound in a relatively long period of time, the microorganisms will adapt to it. This phenomena is denoted acclimatisation.

The degradation processes can be divided into four major phases as depicted in Figure 5.1; hydrolysis, acidogenesis, acetogenesis, and methanogenesis.

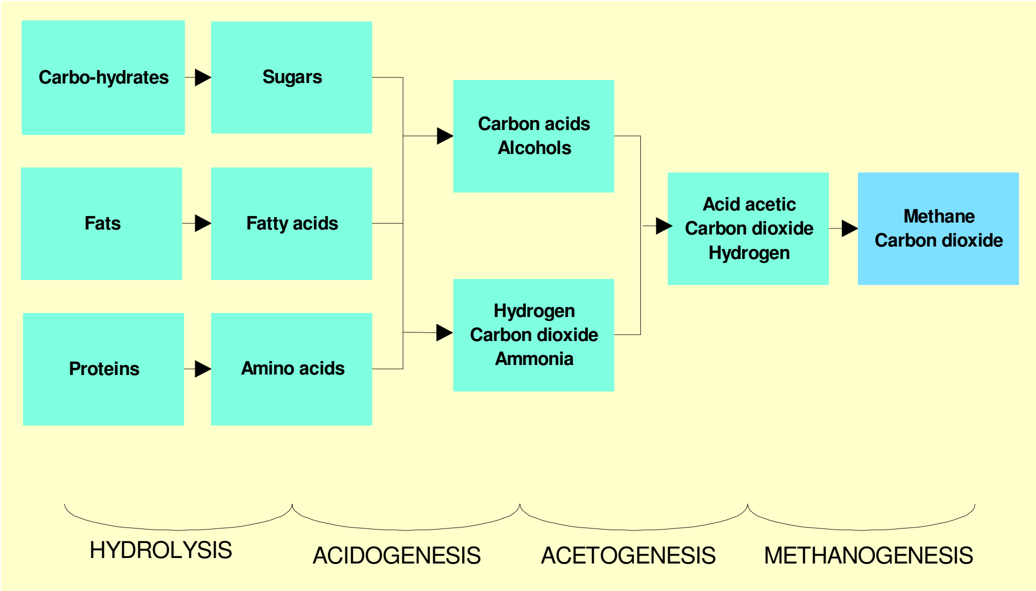


Figure 5.1. The four main phases of anaerobic digestion

Each of the four steps relies on certain microbial consortia to perform the conversion processes. Some consortia are highly tolerant and can utilise multiple substrates, while others are very sensitive towards environmental changes and in addition are only capable of utilising a single substrate. Hence, in order for the four degradation steps to be in balance, the overall chemical environment in the biogas reactor has to satisfy the needs of all consortia at all time.
The methane formation step is the most sensitive of the four process steps. The methanogenic consortium is very sensitive towards fluctuations in the pH value and are severely affected if it drops below 6. Moreover, their growth rate is slow compared to the other consortia. Hence, they are in risk of being both out-grown and washed out. Proper control of the chemical environment in the reactor is therefore of utmost importance in order to keep the methanogenesis working. Otherwise the reactor *can* be imbalanced.

Hydrolysis

The first step in the anaerobic degradation is the hydrolysis. Hydrolytic and fermentative microorganisms excrete hydrolytic enzymes that convert biopolymers into soluble compounds. Lipids, polysaccharides, nucleic acids, and proteins are converted to mono- and oligomers such as glucose, glycerol, purines, pyridines, and many more. The smaller molecules can, in contrast to the larger biopolymers, be utilised by the fermentative bacteria and converted to acetogenic and methanogenic substrates. Hence, the hydrolysis is an important step enabling fermentation and subsequently biogas formation.

The fastest hydrolysed compounds are lipids followed by carbohydrates, proteins, and solid waste mixture. The carbohydrate group represents a broad portfolio of compounds spanning from simple sugars to plant biomass constituents.

Effective hydrolysis of plant biomass, which is made up by cellulose, hemi-cellulose, and lignin, requires some sort of pre-treatment, since the lignin complex effectively protects the convertible cellulose fibres. Plant biomass is therefore protected against microbial degradation to a large extent.
It is considered that the rate of hydrolysis depends on the adsorption of hydrolytic enzymes to the surface of the organic particles. The larger the surface-to-volume ratio, the more efficient the hydrolysis. Hence, mechanical comminution of feedstocks minimising the particle size and increasing the relative surface area should be considered. In the case of manure, where a large part

of the dry matter is made up by plant fibres (lignocellulose) that are hard to convert biologically, mechanical pre-treatment can significantly improve the conversion rate and the gas yield.

Acidogenesis
In the acidogenesis, the products from the hydrolysis are converted by the fermentative microbial consortia into methanogenic substrates, which include volatile fatty acids, alcohols, carbon dioxide, and hydrogen.
Volatile fatty acids constitute the most frequently encountered intermediate products in anaerobic digesters. Approximately 30 % of the hydrolysis products will be converted into volatile fatty acids and alcohols. In case of an imbalanced process, the concentrations of volatile fatty acids will continue to rise, affect the chemical environment including the pH, and eventually lead to process failure.
Hydrolysis of cellulosic material yields the monomeric sugar glucose. Therefore, glucose is a reasonable model compound for description of the fermentation step in anaerobic digestion. A wide variety of fermentation products can be formed from the same substrate. Under a given set of operating conditions, the acidogenic microorganisms chose the thermodynamically most favourable metabolism. Hence the product formation depends on the current conditions in the biogas reactor.

Acetogenesis
During the acetogenesis, products from the acidogenesis are converted onto methanogenic substrates (acetate, carbon dioxide, and hydrogen), since not all fermentation products can be converted to methane by the methanogenic microbial consortia. For instance, volatile fatty acids with carbon chains longer than two units and alcohols with carbon chains longer than one unit need to be oxidised into acetate and hydrogen. This operation is performed by the acetogenic consortia during acetogenesis.
Propionate is degraded via the methylmalonyl-coenzyme-A pathway. The products of this reaction are acetate, hydrogen, and carbon dioxide. Butyrate is converted to acetate via β-oxidation. Valerate degrades to a mixture of acetate and butyrate via β-oxidation also. Iso-butyrate is first converted to converted butyrate and then degraded via β-oxidation to acetate and hydrogen.

It has been shown that propionate has the slowest degradation rate of the volatile fatty acids.

Methanogenesis
The methanogenesis constitutes the final step in the anaerobic digestion. Methane can be formed from acetate and hydrogen respectively. 70 % of the formed methane arises from acetate, while the remaining 30 % come from conversion of hydrogen.
The operating conditions have severe influence on the methanogenesis. Composition of the feedstocks, feeding rate, temperature, and pH are examples of parameters that affect the methanogenesis.
Methane formation from acetate has a lower temperature limit at 37 ºC. The optimum temperature has been found to be 63 ºC.

Digestion parameters

In order to enable efficient operation of the anaerobic digestion process, a number of operation parameters must be controlled. The following describes the most important of these parameters.

Temperature
Anaerobic digestion processes can be run at different temperatures. Usually, the different operating ranges are divided into three groups: psychrophilic (below 25º), mesophilic (25ºC - 45ºC), and thermophilic (45ºC- 70ºC). The definitions might vary from reference to reference.

The highest growth rate is obtained at thermophilic temperatures. Since methanogens are slow-growing, the high growth rate at thermophilic temperatures is desirable. However, there is a price to pay in the form of a number of disadvantages. These include:

- elevated risk of ammonia inhibition
- maintaining a high temperature requires relatively more energy
- higher degree of instability

Still, the advantages outperform the disadvantages, if the biogas plant manager knows, how to keep the process within *safe operating conditions*. The advantages for thermophilic operation are:

- effective pathogen reduction
- increased organic load is possible or
- reduced retention time enabling higher substrate throughput
- better degradation of solid substrate means better substrate utilisation
- increased solubility of hydrolysis products causes higher biogas yield

The higher operation temperature results in faster chemical reaction rates, higher solubility, and lower viscosity. One of the most important effects of these many factors is that the substrate is better utilised compared to mesophilic conditions. The demand for more process energy to maintain thermophilic temperatures can therefore be justified by the higher biogas yield.
It is important that the process temperature is kept constant to maintain a sound microbial environment. Otherwise the biogas production will drop until the bacteria have adapted to the new temperature. Temperature fluctuations will therefore affect the biogas production and thus the overall plant economy negatively.

pH
The methanogenic consortia exert the highest *intolerance* towards fluctuations in the pH. The recommended pH interval is from 6,5 to 8, which is quite narrow. Below pH 6,6 the methanogens grow very slowly and are thus in risk of being washed out of the biogas reactor.
Monitoring of pH can, however, give a false impression of the state of the process. This is because buffer capacity is provided by for instance bicarbonate. The buffer effect is first consumed, if accumulation of acids occur. The pH will remain stable through this buffer consumption. Afterwards it can drop drastically, totally inhibiting the methanogens. Therefore pH cannot be recommended as a stand-alone monitoring parameter. It has to be compared with the buffer capacity, both total alkalinity and bicarbonate alkalinity.
pH is assessed via an electrode that is immersed into the reactor. Due to microbial growth on the sensitive glass membrane of the electrode (known as fouling phenomena), the reliability of the measurement might be comprised over time.

Ammonium
Degradation of manure and protein rich feedstock causes ammonium to be released in the reactor. Ammonium is an important nutrient in many of the microbial processes. However, depending on the chemical environment, ammonium can be toxic and inhibit the process. It has been proposed that the species responsible for inhibition is the unionised form of ammonia, NH_3, also referred to as free ammonia.

The concentration of free ammonium increases with temperature. Therefore, anaerobic digestion processes operated at thermophilic temperatures are more vulnerable towards ammonia inhibition than processes run at mesophilic temperatures. pH has an even greater influence on the toxicity of ammonia than temperature. The free ammonia penetrates the cell walls of the bacteria and by this affect the ion balances inside the cell.

Volatile fatty acids

The main intermediate products of the anaerobic digestion, the volatile fatty acids, have been proposed as valuable process indicators by several authors. Acetate is normally found in concentration of approximately 80 % of the total volatile fatty acids. The second most important acid is propionic acid. The longer acids are normally found in much smaller amounts.
However, each and every biogas reactor behaves *differently*, as indicated previously in this section. No two reactors can be compared based on concentrations of volatile fatty acids. Volatile fatty acid concentrations that might completely inhibit one reactor can be the normal operating conditions for another reactor, mainly because the inoculum in a biogas reactor can be adapted to extreme conditions over time.

Gas quality

The quality of the produced biogas can be assessed and provide the plant operator with important information about the state of the anaerobic digestion process. Normally, the methane content and the humidity (water content) are determined at the biogas plant by commercial sensors quantifying the calorific value of the biogas. Another relevant gas quality parameter is hydrogen sulphide.
The gas quality can, however, not be used as a stand-alone parameter to detect process imbalance. It has to be compared with other available data including the feeding strategy, the gas production rate, pH, alkalinity, and preferably also the volatile fatty acid concentrations.

Gas production rate

A sudden drop in the gas production rate can be due to several reasons. Insufficient substrate concentration, inhibition or organic overload of the anaerobic digestion process can be some of the reasons. In case of insufficient substrate composition the problem can be solved by changing the feeding strategy and by this ensure a more stable biogas production. Organic overloading can occur, if a feedstock rich in easily digestible compounds is fed to the reactor. For instance, the organic fraction of municipal solid waste often contains lipids that are degraded quickly. An over-optimistic feeding of might then lead to organic overloading, which often results in a slightly higher gas production followed by a heavy reduction in the gas production rate. Finally, inhibition from various chemical species can be the reason for the reduced production. Increased concentrations of ammonia and volatile fatty acids or drop in alkalinity and pH can be causing the inhibition resulting in reduced biogas yield. Moreover, feedstocks like for instance pharmaceutical by-products containing compounds that are toxic for the microorganisms in even small amounts can be responsible for the inhibition.
The gas production rate cannot be used as a stand-alone control parameter, but has to be combined with the feeding strategy and other available parameters to give a clear indication of the state of the process and to detect upcoming process imbalance.

Centralised co-digestion of multiple substrates (CAD)

Digestion of solely manure yields a low biogas production due to the composition. The dry matter content in pig and cattle manure is usually spanning from 2 to 5 % with the vast majority of this dry matter being plant fibres.
Co-digestion of manure and other organic feedstocks solves many practical problems. The high water content in manure ensures that the fermentation broth is diluted sufficiently to allow efficient mixing of substrate and microorganisms. Nutrient deficiency in single substrates is counter-acted when co-digesting. Especially, nitrogen, carbon, sulphur, and phosphorous have to be present in the blend in optimal proportions. Trace metals have to be present in adequate amounts in order for the microbial processes to perform satisfactory.

A significant part of the produced amount of biogas in Denmark arises from manure co-digested with industrial organic waste. Two types of biogas plant are in operation; the decentralised farm-scale plants, treating manure from a single farm or a few farms, and the centralised co-digestion plants, normally operated as cooperatives or as private limited companies. A larger number of farmers supply manure to the centralised plant. Moreover, significant amounts of suitable organic residues are added to the process, hence the term *co-digestion*, in order to enhance the biogas yield and thus strengthen the economic bottom line. The economic performance of the centralised biogas plants to a large extent dependent on the availability of high quality organic residues.

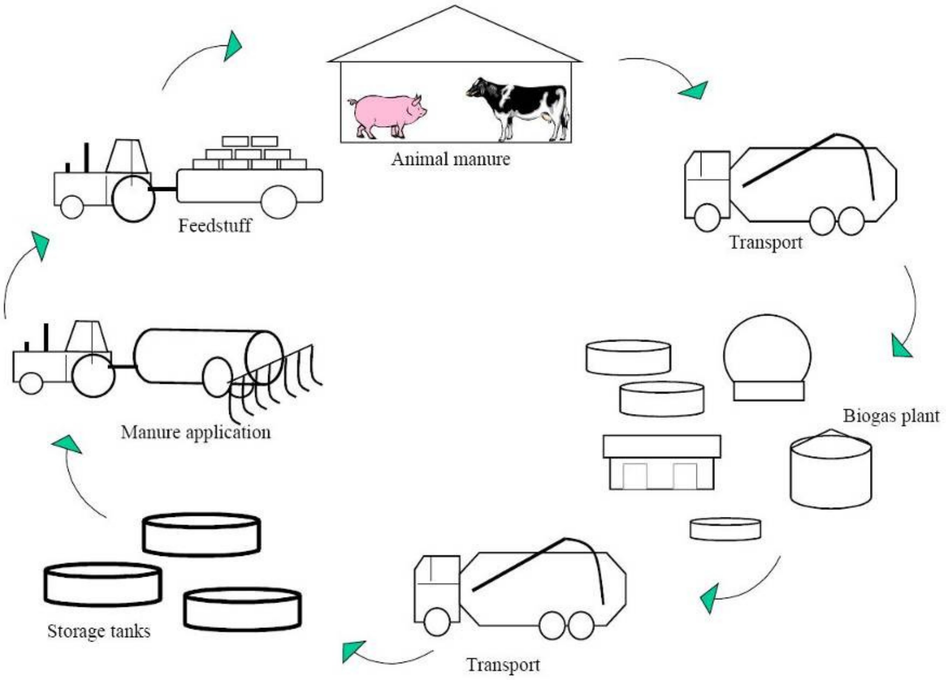


Figure 5.2. The centralised biogas plant in a traditional manure handling chain

At present, 21 centralised co-digestion plants and approximately 60 farm-scale plants are in operation in Denmark. Together, they treat 1,5 million tonnes of manure and 0,3 million tonnes of industrial organic waste annually.
The Danish centralised co-digestion concept involves the agricultural sector, the energy production end distribution sector, the food industry and agro-industry sector. The result is an optimised and integrated biological production system; a biorefinery. The centralised biogas plant concept is depicted in Figure.

Additional organic feedstocks e.g. energy crops, agricultural by-products, and suitable industrial organic waste can be co-digested with animal manure in a biogas plant. The products from the biogas plant constitute organic fertiliser and biogas; two high-value products of great socio-economic importance.

Some of the features of the centralised Danish concept are that nutrients contained in pig and cattle manure produced by agricultural activities can be re-distributed among crop cultivators. Hence, farmers having many livestock units and too few hectares of farmland to apply the manure on according to Danish law, can re-distribute nutrients (nitrogen and phosphorous) via the centralised biogas plant to for instance crop farmers having plenty of land, but no livestock units. Moreover, the anaerobic digestion process effectively reduces the offensive odor traditionally associated with raw manure and it also eliminates pathogens, weeds, and deceases.
The composition of the co-digestion substrate consisting of manure and other organic substrates is set by legislation. Minimum 75 % of the biomass has to be manure. A sector analysis performed by Aarhus School of Business in 2005, estimated the global market for manure handling to be worth DKK 740 billion (~EUR 100 billion).
The simple mono-substrate configuration based on manure is not economically viable under Danish conditions. Organic substrates resulting in higher biogas yield *have* to be added to the biogas reactor in order to boost the gas production and ensure an economically feasible process. These additional substrates can for instance be the organic fraction of source-sorted municipal waste (OFMSW), organic industrial by-products (fats, oils, spirits etc.), and energy crops (various silages, whole crops etc.).

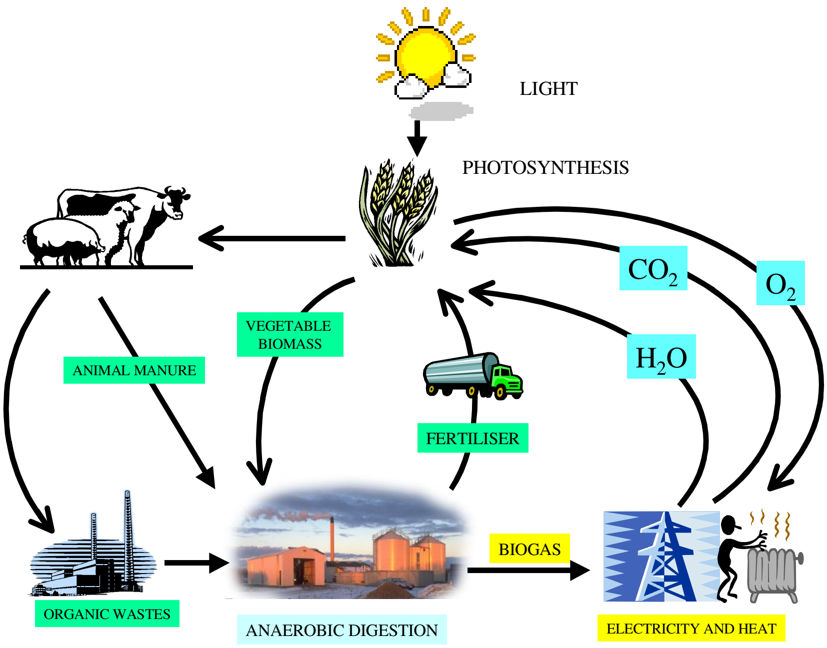


Figure 5.3. The centralised anaerobic co-digestion concept

A recent Danish socio-economic study investigated different scenarios, where centralised biogas plants were operated *without* addition of industrial organic resources. The aim was to analyse the feasibility of digesting solely farmyard manure. It was concluded that a combination of separation of the manure at the farms and centralised physico-chemical pre-treatment of the lignocellulosic fibre fraction could lead to a doubling of the practical biogas yield. The pretreatment technologies included wet-oxidation and pressure cooking. As of today, a large portion of the biogas potential in manure is recalcitrant and leaves the biogas plant via the effluent; the complex lignocellulosic structure of plant material is difficult, practically impossible, to degrade biologically.

The centralised co-digestion – a closed biomass cycle plant is situated centrally, in a high density manure area. Animal slurries and manure from several farms around are supplied to the plant, to be co-digested with various types of suitable organic wastes from agriculture and from food processing industries. The biomass substrate is usually transported to and from the centralised digestion plant (CAD) in vacuum trucks.

The substrate (slurry, manure, organic residues) is sanitised and digested in anaerobic reactor tanks. The average retention time in the digesters is of 15 days. The biomass substrate is continuously pumped in the reactor, as the digestate is pumped out and transported to storage tanks located next to the fields where digestate will be used as fertiliser.

The biogas produced is continuously collected and transported by pipelines to the energy production unit, where it is converted into heat and electricity in a combined heat and power unit. The electricity is sold to the grid and the heat is used at the biogas plant as process heat, while the main part is sold to heat consumers (housing or industry).

The centralised co-digestion concept, developed in Denmark is a multifunctional technology providing renewable energy and benefits for the agriculture and environment. The environmental friendly, renewable energy production is used to substitute fossil fuels and thereby increases security of energy supplies and to reduce dependence on imported fossil fuels. The co-digestion of manure helps the farming sector to handle and to redistribute the surplus of manure in other areas, where it could be used in environmentally friendly ways. Co-digestion provides an economically attractive and sustainable management of organic wastes and improves the fertiliser value of the animal manure and slurries. CO_2 emissions and losses of nitrogen to water systems are reduced and the establishment and operation of the biogas plant leads to creation of new local jobs and supports the rural economies.

Centralised co-digestion biogas plants can be organised in different ways. In Denmark, the co-operative companies owned by farms are widespread. Sometimes heat consumers take part in the co-operation, but also limited companies and private foundations are co-owners. When the plant is not owned by the farmers, they often form a manure supply association, to represent their interests in their relation with the biogas plant and the company behind it.

6. Digested manure is a valuable fertiliser

In Denmark, digestion of slurry is recognized to contribute to a better utilization of the slurry as fertiliser. From a large number of field trials this has been documented. It is also evident that digestion reduces the smell problems after spreading the slurry.

Table 6.1 describes the most important advantages from an agricultural and an environmental perspective.

Table 6.1. Advantages of biogas production for the energy sector, agriculture and the environment

Energy sector	Agriculture	The environment
• energy production • CO_2 neutral	• improved utilisation of nitrogen from animal manure • balanced phosphorus/ • potassium ratio in slurry • homogeneous and light-fluid slurry • reduced transportation of slurry • possible to get large amounts of slurry with a full declaration of contents • slurry free from weed seeds and disease germs	• reduced nitrogen leaching • reduced odour problems • reduced greenhouse gas emissions • controlled recycling of waste

What is digested slurry?

Digested slurry must is used in the same way as raw slurry. However, there are some important differences. The distinctive features of digested slurry are:

- that several types of slurry and waste are mixed
- that the organic matter is partly degraded

Table 6.2. Content of dry matter, nutrients etc. in slurry used in field trials at Danish Agricultural Advisory Service in 1999-2001. In () the number of samples are indicated. The digested slurry used is likely to be a digested mixture of about 50% pig slurry, 25% cattle slurry and 25% organic industrial waste

	Dry matter, %	N-total, kg per tonne	NH_4-N, kg per tonne	P, kg per tonne	K, kg per tonne	pH factor	NH_4-N-share, %
Digested slurry (20)	4,8	4,4	3,5	1,0	2,3	7,6	81
Pig slurry (28)	5,0	4,8	2,9	1,1	2,3	7,1	74
Cattle slurry (15)	7,5	3,9	2,4	0,9	3,5	6,9	61

To consider the nutrient value of nitrogen it is important to notice that:

- The dry matter is relatively low in digested slurry due to the degradation in the biogas reactor. This makes the slurry more liquid.
- The ammonium (NH_4-N) content is higher than in untreated slurry due to degradation of organic bound nitrogen in the reactor.
- The pH factor rises due to degradation of organic acids in the slurry. This increases the risk of ammonia volatilization.

Digestion increases the fertilizing effect of slurry

The physical and chemical process taking place in the biogas plant changes the fertilizing effect of the slurry in the field. It is important to make allowance for this when the fertilizing plans are prepared and also when handling and spreading the slurry. In the planning process the high content of ammonium has to be considered. This high content is advantageous to the crops as they are primarily capable of utilising ammonium nitrogen. In other words: It is often possible to replace nitrogen from commercial fertiliser by digested slurry and thus save money.

Figure 6.1. Biogas plants contribute to a better utilisation of nutrients in the agriculture. Photo cortesy of Torkild Birkmose, DAAS

The thin, low-viscosity digested slurry seeps relatively quickly into the soil. This reduces the normally very high risk of ammonia volatilization. Trials have shown that the ammonia evaporation from surface applied digested slurry actually is lower than from surface applied pig slurry.

Field trials with digested slurry in winter wheat have demonstrated nitrogen utilization higher than pig slurry and much higher than cattle slurry (Figure 6.2). This means for example that if a farmer fertilizes a field of winter wheat with 170 kg of total nitrogen in digested slurry in stead of 170 kg of nitrogen in cattle slurry, he can save about 54 kg of nitrogen of mineral fertiliser and still get the same yield!

By reducing the supply of nitrogen in mineral fertiliser a reduction in nitrate leaching can be expected. The specific reduction is dependent on the autumn and winter cover of the fields, the soil type etc. In general a reduction in nitrate leaching of 0.33 kg nitrate-N per kg reduction in nitrogen in mineral fertiliser was used in the evaluation of the second Danish environmental protection plan.

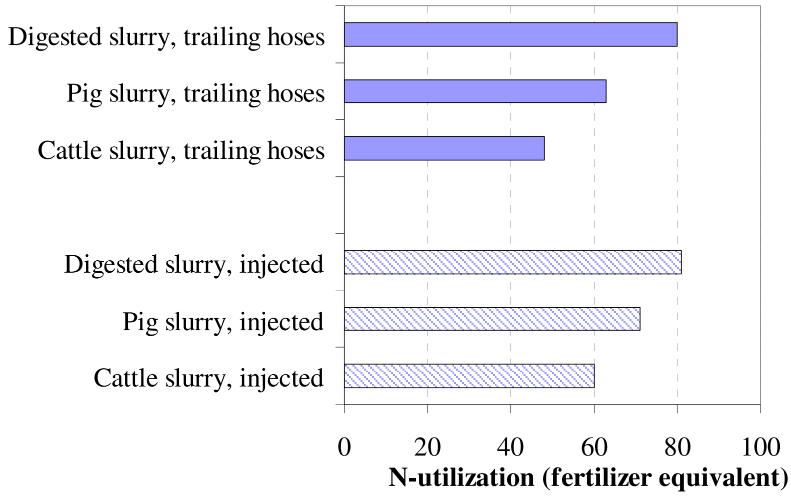


Figure 6.2. Utilization of nitrogen in digested slurry compared with pig and cattle slurry in field trials at Danish Agricultural Advisory Service. Average of 11 trails with digested slurry, 15 trials with pig slurry and 15 trials with cattle slurry

Phosphorus and potassium

The utilization of phosphorus and potassium in animal manure is normally a matter of avoiding oversupplying the crops. The best solution is only to supply until the requirement of for instance phosphorus is covered. If the requirement of potassium is not covered at the same time extra potassium in mineral fertiliser must be supplied.

The phosphorus/potassium ratio of digested slurry is often about 1:3. This ratio is excellent for crop rotation schemes including for instance grain and rape - these crops often require about 20 kg phosphorus and about 60 kg potassium. Crop rotation schemes dominated by roughage crops require extra potassium from commercial fertiliser as the demand for potassium is much higher in for instance grass, beet and maize, than in cereal and rape. If a relatively large share of the slurry to the biogas plant originates from cattle the phosphorus/potassium ratio of the digested slurry will be considerably higher, and the slurry will be more suitable for roughage crops.

Digestion reduces the smell from the slurry

In a biogas reactor almost all easily degradable organic compounds are degraded and converted into biogas (methane). Amongst these compounds are a lot of volatile organic compounds that smell very bad. For example a great number of fatty acids. When these compounds are degraded, the smell will be reduced compared to untreated slurry after spreading on the fields. In Figure 6.3 the content of four fatty acids in untreated and digested pig slurry is shown. A significant reduction is demonstrated.

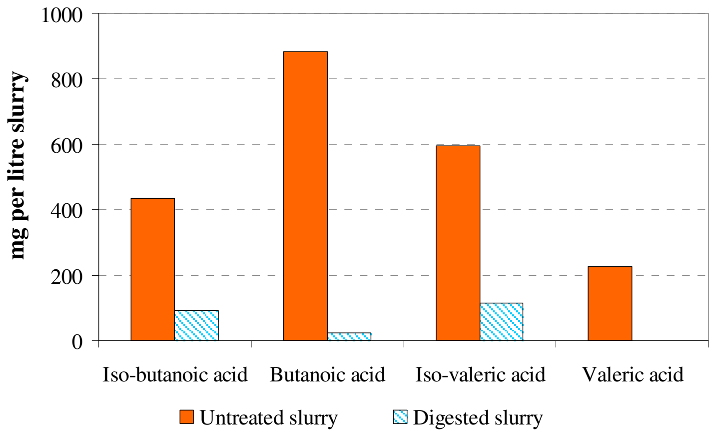


Figure 6.3. Concentrations of four very bad smelling volatile fatty acids in untreated and digested slurry

7. The case studies

The selected case studies are represented by regions with intensive livestock production, with a certain potential for biogas production and with no or very little developed biogas technologies. The regions listed in Table 7.1 were selected as case studies for the PROBIOGAS project

Table 7.1. Selected regions for the six case studies

Country	Location
Ireland	North Kilkenny county
The Netherlands	Bladel, region de Kempen, north Brabant
Belgium	Province of Liège, Wallonia
France	West Aveyron, Midi-Pyrénées
Spain	Pla d'urgell, Catalonia
Greece	Sparta, Tsikakis-yiannopoulos pig farm

The selected case study in Ireland: North Kilkenny County

By Vicky Heslop

The Irish Case study was selected to be near the village of Ballyragget, where there is a very large dairy processing factory. Ballyragget is situated in North Kilkenny, which is in the north-west corner of the South East Region of Ireland. It is therefore a very central location, within the whole of Southern Ireland. The Dublin to Cork motorway passes within 8km of the potential site, and the feed road from the prosperous South-East of Ireland, is adjacent to the potential site and joins the Cork-Dublin road at this point. This CAD would therefore be well situated to receive non-farm waste.

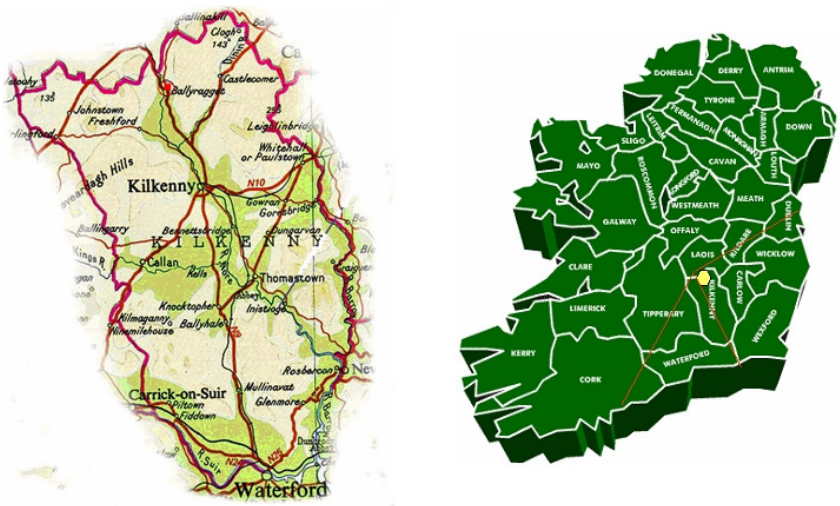


Figure 7.1. Left: map of County Kilkenny. Right: the location within Ireland

The project

However, the other local roads are winding and narrow. Apart from keeping the transportation costs as low as possible, this is an other reason that the slurry collection and for the use of the liquid digestate is kept to a limit of 8km radius. North Kilkenny is sparsely populated, being mainly an agricultural area, with small (>250 people) villages. Ballyragget the nearest village (1 km) has a population of 200 people, the next village is 10 km distant. Most of the communities in the area have suffered from rural degeneration, due to people leaving farming and insufficient local jobs to stop young people from leaving for the cities. Recently this de-population has started to slow down and has been reversed in some areas, by people from towns building new houses to live in. However, this has resulted in an increase in traffic and little benefit to communities, as most of these people work in towns away from the area. Many of the newcomers are unused to the smell of manure, and do not want the manure smell close to their homes.

The geology of much of the area is shale over limestone, has many rivers, and large areas are prone to flooding. Therefore the risk of water pollution of the ground as well as the surface waters is quite high in the area. The area has two significant waterways, Nore and Barrow rivers, flowing through and being fed by tributaries that rise in the upland areas. Most surface water has higher than acceptable levels of nitrogen and some parts are extremely high in nitrogen. There are now some signs of increasing nitrogen levels in ground water, originating predominantly from sewage management in rural communities, and agricultural runoff. Eutrophication caused by phosphate is also present in some local waterways.

Regulatory environment
National and EU Regulations

- EU and Irish Regulations concerning animal by-products
- Irish Nitrates Regulations
- Sludge use in agriculture
- EU Landfill Directive and Irish Waste Strategy
- National Climate Change Strategy (NCCS)
- Irish Renewable Energy policy
- CAP Reform

Licences/permissions to be obtained

- Planning permission from Kilkenny County Council
- Waste License from the EPA
- ABP License from the Department of Agriculture
- License from Commission for Energy Regulation (CER) to build a generating station
- License to generate from CER

Table 7.2. Summary of the Regulatory Environment in December 2005[1] and June 2007

Regulation	Dec 2005	June 2007
ABP	No spreading on agricultural land	Catering waste permitted with 3 week grazing ban. Former foodstuffs permitted with 3 year ban on animal access. All raw meat must be rendered
Nitrates Regulations	Controls all organic fertiliser application to land at <170kg/ha and controls on P and spread times 60% grant for storage	<170kg/ha only applies to manure and some small change in P limits which applies to all organic fertiliser 40% grant for storage
Waste Strategy	General targets for landfill diversion in place	Biodegradable waste strategy sets specific targets and a development programme for marketing digestate
NCCS	Reduction targets of 60k tpa from manure storage, & 900k tpa from fertiliser use. Large heat users in ETS	Achieved by Nitrates Regulations specifying an increase in available N from manure of 20% in 2007-2010 Allocations increased
Renewable Energy	Price support through REFIT of 7.2/kWh for RE electricity supplied Target of 13.2% RE elec by 2010	White Paper on sustainable energy sets heat targets from RE
CAP Reform	Uncertainty of the future for small farms	Large increase in part-time farming and land leasing

Description of the proposed CAD

About 40 dairy and cattle farms in the area will supply about 34,000tpa slurry, farmyard manure, silage effluent and other farm organic waste to the CAD. The size of these farms varies from 30-350 livestock units (LSU). These farms currently allow the raw dairy sludge to be spread on their grassland. Some of these farms also have arable land that would be available for spreading digestate products. There may also be sufficient digestate products to supply some other arable farms in the area. These additional farms are available.

The dairy processing factory produces 16-18,000tpa of sludge and fats from its wastewater treatment works. This sludge is currently stored during the three months of winter when spreading is not permitted, and then spread on grassland. 8,000ha of grassland is signed up to the factory to ensure they have sufficient spreading land. Some of this land is 25km distant to the factory and only about 30% is currently spread on the farms that will work with the CAD. So there will be a significant saving in transport and spreading costs for the factory. These costs amount to €12.50/ton sludge, and this is the gate fee the factory would be willing to pay the CAD.

There is also the potential to treat kitchen waste from households and sewage sludge produced by small community treatment systems. A much higher gate fee of €40-70/ton could be charged by the CAD for taking this material. But due to the national ABP Regulations in place in 2005

[1] The case study assessment was based on conditions in December 2005

and the parameters of the model used in the case study assessment, these wastes were not included.

In total 143tonnes of material would be processed each day, requiring a digester with a capacity of 3,000cu m. The dairy WWTP sludge is produced all year round, although there is less produced in the winter months. The cattle are only housed for about 5 months through the winter. To ensure a steady feed for the digester, some of the slurry and all the FYM will be stored on farms to provide the summer feed.

Table 7.3. Inputs and gas production

	Quantity tpa	DM	CH_4 m^3 pa	Gate fee €
Slurry	31,132	7%	343,697	0
FYM	3,240	25%	77,760	0
Dairy sludge/fats	18,000	14%	691,200	12.50/t
Total pa	52,372	10.5%	1,112,657	225,000

For the purposes of the PROBIOGAS assessment the digester system design was taken to be a standard Danish CAD model with a CHP unit to utilise all the biogas produced and to produce electricity and heat. For the Irish case study a centrifuge was also included to separate the digested material into a liquid fertiliser and a solid fibre fraction. The centrifuge was included because of

a) the need to manage the phosphate distribution,
b) most of the land to be spread is grassland, and the separated liquor is a better grassland fertiliser than whole digestate, because there is virtually no surface residue after spreading and the nitrogen availability is higher (90 % instead of 70 %)
c) the fibre, contains the majority of the phosphate and is ideal for arable production and excess can be transported out of the area cost effectively, and initial investigations have shown there is a market for this product for the manufacture of compost products.

Table 7.4. Division of digestate with separation by centrifuge

	Digester effluent	Liquid	Solid
Volume split kg	1000	915	85
Dm %	4.7 %	2.2 %	32 %
N division		73 %	27 %
P division		29 %	71 %

Other types of separation equipment could be used instead of a centrifuge. This might be desirable because the capital and operational costs of a centrifuge are high and are lower for other types of separation. However, the division of materials and the nutrients would vary with different types of separator.

Use of outputs from digester
For the purpose of the case study assessment, it was assumed that all the biogas would be used in a CHP to generate electricity and heat. And that all the electricity produced would be ex-

ported via the grid at 7.2c/kw hour, and that the heat would be used entirely for process heating and within the factory. Electricity required for the process would be bought-in at the same price as sold. However, if this project were to be developed, it would be likely that only some of the biogas (about 40%) would be used in a CHP, of a sufficient size to provide for digester process heating. That the electricity produced would be used for process needs with only the surplus being exported to the grid. The majority of the biogas would be piped to the factory to be used to produce steam. The decision of how to use the biogas would be dependant on the relative value of natural gas and electricity at the time.

For the purposes of the case study it was assumed that all the digested material would be separated in a centrifuge. And that all the liquid fertiliser but only a small amount of fibre would be used locally, the rest of the fibre would be transported about 60 km and utilised as a fertiliser product. This approach was necessary to avoid complication in the model used for assessment. However, this approach does not optimise the use of nutrients locally, nor is it the best economic or environmental strategy. If this project were to proceed it would probably be preferable to maximise the amount of artificial fertiliser replaced by the digested products. This could be achieved by using a mix of the three products. The actual type, mix and quantity of product used, would depend on actual soil status, nutrient requirement of the crop grown and timing of application.

For example, on grassland used for one crop of silage in the spring and then grazed until the cattle are taken in. Depending on the soil and weather conditions either whole digestate or liquor could be applied before and after silage. Liquor only would be used during grazing, to ensure maximum N availability and no spoiling of grazing. And fibre could be spread after the last grazing, to supply Phosphate and replace organic matter removed with the silage crop.

Table 7.5. Utilisation of digestate

	silage	Post silage	End July	After last grazing
Type of product	Whole/liquor	Liquor/whole	liquor	fibre

The benefit for both the farmer’s pocket and the environment could be maximised if the approach was taken, whereby the digestate products were used as the basis of nutrient management planning and by utilising a mix of products to meet all the Phosphate requirements of the crop (considering the soil P status of the land), without exceeding an application rate of 170kg of N/ha from animal manure.

Economic assessment

The economic calculations are carried out as an analysis of the difference between a reference case and the case study based on a whole system analysis. The whole system analysis includes the whole system from manure pre storage tanks on the farms to the nutrients being utilised as a fertiliser in the fields. All the farms connected to the CAD are included, including crop farms and horticultural outlets that are assumed to receive surplus digestate in the CAD situation. The benefit for farms is calculated as an average for all. The relevant costs are calculated for the whole system, both in a reference situation, and in a fully operational CAD situation. The reference situation is based on Danish experience, the case study assessment used data supplied from Ireland and existent in December 2005.

Table 7.6. Basic preconditions

Parameter	Unit	Value
Required storage capacity solid manure, reference	Months	9
Required storage capacity liquid manure, reference	Months	4
Required storage capacity fiber fraction, case study	Months	2
Required storage capacity liquid manure, case study	Months	6
Price, electricity sold	Eur per kwh	0,07
Price, electricity, own production for process purposes	Eur per kwh	0,07
Price, heat sold	Eur per mwh	20
Treatment fee, dairy wwtp sludge	Eur per tonne	12,5
Capacity of trucks in use, solid/liquid	Tonnes	20/30
Capacity of trucks in use for long distance transportation of fiber	Tonnes	30
Average speed, transport vehicles local roads	Km/h	30
Average speed, transport vehicles long distance transport	Km/h	60
Average distance from storage to land	Km	0,75
Average distance from farm to cad	Km	4
Average distance, long distance transport, liquid/fibers	Km	10/50

Value for farmers

The assessment estimated that the net benefit for farmers was €4/ha which is much lower than in other case studies. There were several reasons for this

a) the farmers in the case study area already receive raw dairy sludge, and derive some nutrient benefit thereby already.
b) In 2005 Teagasc advice was that only 50% of the ammonia N in manure was available to crops. The assessment therefore assumed that only 50% of ammonia-N was available in manure/sludge and digested products. With proper management of digested products it is usual that 100% of ammonia-N will be utilised, therefore twice the amount of artificial N could be replaced.
c) To be in accordance with the Nitrates Regulations in 2005 no more than 170kg/ha of total N from organic fertilisers could be applied. This limit has now been changed to 170kg/ha of N from manure. Therefore, the amount of digested product that can be applied has increased to almost double because nearly 50% of the N in the digested products comes from the dairy sludge and not manure.
d) Currently the farmers do not have the expense of spreading the dairy sludge, with the CAD situation they will have additional volumes to spread, and therefore additional costs
e) The farmers will require additional storage facilities for the digested products. This cost was set against the fertiliser saving benefit. If farmers could avail of storage grants the amount of saving would increase.

Table 7.7 Economic performance of the Irish CAD

Costs	1000 EUR	income	1000 EUR
Electricity purchase	-25	Electricity sales	275
Maintenance	-127	Heat sales	92
Sand removal	-2	Waste gate fees	225
Insurance	-18		
Other	-18		
Staff	-103		
Premises	-6		
Administration	-15		
Capital	-336		
Transport	-111		
Waste storage costs	-22		
Separation of digested manure	-40		
Costs in total	-883	Sales in total	572

The economic assessment, given the conditions, is that the CAD in the Irish case study would operate at a loss of €311,000pa.

In this conditions it would not make sense to develop the CAD. However, a small change in any one of the parameters could be sufficient to make it viable to develop the CAD.

Socio-economic assessment

The socio-economic analysis looks at the biogas-scheme from the point of view of the society at large. Therefore all consequences of the scheme in any sector of society should in theory be taken into account, - including externalities. Externalities, or external effects, imply neither expenses nor income for the corporate or private investor. However, a project may inflict burdens or contribute gains for the society relative to the reference activity, which must be taken into account when evaluating a project from the point of view of the society. Only those effects where verifiable data is available have been included in the calculations. Those omitted include, security of supply, saved resources, global balance of trade, effect on infrastructure (eg roads, grid), Sox/Nox, animal and human health benefits, employment and rural development benefits.

Greenhouse gas emissions

The case study assessment has calculated that 71kg of CO_2 equivalent are saved per ton of biomass treated. This amount would increase considerably if the CAD could process wastes that would otherwise be disposed of to landfill. The CO_2 savings represent 90% of the GHG emissions avoided, whereas with most CAD, other gases make up 50% of emissions avoided. Therefore if the Irish CAD could process ABP waste the GHG emissions avoided would be much higher. The saving in emissions in the case study is calculated by considering the following:

a) methane emissions from stored manure and sludge
b) Nitrous oxide emissions reduction achieved by mineralisation of the Nitrogen during the digestion process
c) The carbon dioxide emissions avoided by replacing fossil fuel (natural gas) to generate the net output of electricity and heat
d) Allowing for emissions of unburned methane (1% of fuel) in the CHP exhaust
e) NPK fertiliser substitution
f) Changes in transportation fuel

Table 7.8. Changed GHG emission

	Gas type	Gas as produced tpa	Equivalent in CO_2 tpa
Electricity sales	CO_2	-1,856	-1,856
Heat sales	CO_2	-1,217	-1,217
NPK substitution	CO_2	-299	-299
Transport fuel	CO_2	32	32
Manure storage	CH_4	0.3	6.3
Sludge storage	CH_4	-9	-189
CHP unburned gas	CH_4	13	273
Manure/sludge/fertiliser	N_2O	1.44	-446
Total			-3,709

For the CO_2 reduction due to NPK substitution the following upstream specific energy and CO_2 contents have been assumed: (38MJ/kg pure N) 9.36kgCO_2/kg pure N, (17MJ/kg pure P) 2.67kgCO_2/kg pure P, and (6MJ/kg pure K) 0.80kgCO_2/kg pure K

The value of the N eutrophication of groundwater is calculated on the basis that the reduced leakage is about 25% of the saved chemical N fertiliser (Brian Jacobsen, SJFI) and that the monetised value of this saving is €3.36/kg N (Ruth Grant, DMU, Denmark).

The value of obnoxious smell avoidance is based on the avoided cost of spreading the manure by soil injection calculated to be 50c/ton. In this case study the cost of avoidance of spreading the dairy sludge could have been included, because the sludge is extremely smelly when untreated, however this avoided cost was not included.

Table 7.9. The socio-economic benefit of the case study

		€
Energy	Electricity sale	136,000
	Heat sale	93,000
Agriculture	Improved manure value	21,000
	Storage, handling & distribution of digestate	- 173,000
	Additional spreading costs for farms	- 27,000
Industry	Disposal cost avoided	225,000
Environment	GHG reduction	96,000
	Reduced N eutrophication of groundwater	38,000
	Reduced obnoxious smells	17,000
	Net socio-economic benefit for CAD pa.	416,000

The Irish Target Group Network (TGN)

Early in 2005 a few people were selected, by the Irish partner in PROBIOGAS, who would be the strategic decision makers concerning the implementation of AD in Ireland. Included were John Curtis and Paraig Larkin of the Environmental Protection Agency (EPA) Strategic Policy section. John Curtis had published a discussion document late in 2004, which discussed the environmental value of CAD. After some discussions it was decided to host a conference jointly between EPA and PROBIOGAS to which all the key people would be invited.

This conference was held in May 2005 and was well attended. The workshop was attended by policy makers, waste producers, farming organisations and those who might assist in marketing the by-products. After the presentations there was a general discussion, to identify and discuss the issues that the delegates had concerning AD and to try to identify how to overcome the barriers to CAD development. The delegates were asked if they were interested to continue to have an input into the PROBIOGAS project with a view to overcoming some of the barriers to CAD development.

One to one discussions were held with most of the TGN. A number of developments have occurred since the conference that the project has had an influence on:

a) A working group was set up by the Department of Agriculture Animal Health Section, to discuss the National Regulations regarding the EU Directive 1774. In the working group representatives from the AD, composting and fish industry meet with Department of Agriculture vets and administrators and civil servants from the waste policy section of the Department of Environment. The meetings have led to a better understanding of everybody's concerns. National ABP Regulations were changed at the end of 2006 to allow correctly processed catering waste to be spread on pastureland with a 3 week delay before grazing, and other category 3 on land where animals will not have access for at least 3 years. Through the working group there is the opportunity to input into a Regulatory review towards the end of 2007.

b) There has been some recognition of the capability of AD to provide better nutrient management. Teagasc (Government Agency for agriculture research and advice) requested a paper from Methanogen Ltd concerning how AD could help agriculture meet the Nitrates Regulations. The Department of Agriculture awarded (early 2007) 40% capital grants to 3 farm based AD projects designed to demonstrate how AD can help intensive agriculture to meet the Nitrates Regulations. It is likely that 3-4 more farm based AD will be awarded grants for this purpose, later this year.

c) The National Biodegradeable Waste strategy published in February 2007, identifies both AD and composting as equally important in providing the infrastructure required to divert biodegradeable waste from landfill and provides €11 million in funding to assist in overcoming the current barriers. There will be a market development group established in September this year to facilitate the implementation of the plan. It is now also recognised that AD provides a more cost effective solution to managing ABP material than composting.

d) Sustainable Energy Ireland has indicated that there will shortly be a capital grant scheme for biomass CHP projects. This will be a standard scheme and applicants will not be required to demonstrate innovative measures.

e) Bord na Mona undertook tests on the separated fibre to determine whether it was a material that would be suitable to use in compost product manufacture. The results were very positive. However, a large volume of the material (about 30t/day) would be required before it would be worth developing the product.

Dissemination activities

- Conference held by PROBIOGAS in co-operation with EPA in May 2005 to present the socio-economic benefits of CAD and to have an open discussion with delegates. Over 60 people attended this workshop. There was 1.5hrs of discussion after the presentations, this was very interesting and informative. The outcome was that it was suggested by the participants that an inter-departmental group was necessary to further explore how to overcome the barriers which were preventing biogas development. Unfortunately this inter-departmental group was not set up despite several efforts by the EPA and the Irish partner of PROBIOGAS to do so
- A workshop in Kilkenny City (nearest town to the case study area) for farmers and agricultural advisors to inform them of the socio-economic value of AD and to encourage discus-

sion of the farming issues connected to CAD. This was found to be very useful to those who attended and there was good discussion concerning the interfacing of a biogas plant with farms and concerning the issues that prevented biogas plants from happening.
- One to one meetings with TGN members to discuss issues pertinent to their responsibilities. This approach was taken, once it became apparent that an inter-departmental group would not be established. This approach facilitated in depth discussion of the issues and the dissemination of the results of the Irish case study assessment.

- Presentation (3/2/07) to the Fresian breeders in Co.Laois/Offally (adjacent counties to case study area) on the potential of AD as a farm management tool at both centralised and farm scale which included results from the Irish case study assessment
- Presentation at the Irish Water and Waste exhibition (8/3/07) which included results from the Irish case study assessment
- Presentations at Waterford Institute of Technology (20/4/07 to agricultural students & 10/5/07 to sustainable development mature students) on AD Presentation to the ABP working group concerning AD which included results from the Irish case study assessment
- Presentation of the Irish Case Study results at the PROBIOGAS conference in Denmark 15/6/07

IRISH WATER WASTE & ENVIRONMENT

sei SUSTAINABLE ENERGY IRELAND

Renewable Energy Information Office

Waste-to–Energy Seminar

Thursday 8 March 2007

The Merrion Room, RDS Main Hall, Dublin

The Irish Water Waste & Environment Show (IWWE) takes place at the RDS, Dublin 7 - 8 March 2007. With over 300 leading suppliers and manufacturers showcasing the latest innovation, technologies and services for water treatment, energy and environmental compliance, this event is an ideal one-stop-shop for environmental managers and consultants, facilities managers, energy consultants, landowners, the pharma-chem and food sectors, and local authority engineers.

During the two-day show Sustainable Energy Ireland's Renewable Energy Information Office are presenting a free Waste-to-Energy seminar on Thursday 8 March at the RDS Merrion Room, Ballsbridge, Dublin.

The seminar will focus on the latest policies, trends, development and future opportunities for the increased deployment of liquid and solid biomass.

Figure 7.2. Advert for the seminar run by SEI at the IWWE at which the presentation was made

- A paper with the title "The Nitrates Regulations and Anaerobic Digestion" prepared for Teagasc in June 2007 at their request about how AD can help farming meet the Irish Nitrates Regulations. This paper identifies the potential of anaerobic digestion (AD) to assist livestock farmers in meeting the Irish Nitrates Regulations (Regulations) and to overcome some of the issues created for farming by the implementation of the Regulations. The paper shows that AD could be used to facilitate the distribution of excess manure by overcoming most of the disadvantages associated with raw manure utilisation. The paper identifies how AD can reduce farm production costs and significantly reduce losses of nutrients to the environment. This paper utilises research results concerning the agricultural and environmental effects of AD to explore why AD can make manure an attractive source of nutrients. However, it becomes clear that there are many things that should be further researched about the effects of AD, to allow a complete analysis to be made. It is unlikely this paper would have been requested without the work of PROBIOGAS project that increased the interest of Teagasc in AD. The paper could not have been written without the information provided by the Danish experts and the case study assessment. This paper has also been disseminated to other policy makers.

- Use of the results of the assessment and Danish knowledge behind the assessments in all my interactions with Government, developers, and other bodies in my normal work as an AD consultant
- Provision of the information gained from PROBIOGAS in the development of a digestate products Standard for UK and the development of a National protocol that defines when a waste, that is processed by AD becomes a product. The protocol and Standard will remove a cost and perception barrier that currently inhibits AD development in UK. The information gained from PROBIOGAS plays an important part in this policy development, because part of the work is to assess the value of AD. Methanogen Ltd has developed the Digestate Product Standard with the Renewable Energy Association (UK industry trade association) and is a member of the technical advisory group to the Protocol development, being led by WRAP (Government Agency responsible for recycling development in UK)

Future dissemination

1. Some of the key policy makers (members of the TGN), have recently agreed that they would be prepared to come to a meeting to discuss AD and where it might assist in meeting their sector's policy targets, and with a view to working jointly to find a way that would create a climate that would encourage AD development in Ireland at small and centralised scale. It is intended that this meeting would have representatives from as many as possible of the different Government Departments/sectors that create policy that affects the development of AD. This tentative willingness to attend such a meeting has only come about because of the work of PROBIOGAS and the one to one meetings held as part of the project.

There is still some way to go until such a meeting can be held, but if it does go ahead it would be a major step to overcoming the biggest barrier to AD development in Ireland, which is policy making and measures that are not co-ordinated. This meeting would be hosted by the Irish Bioenergy Association AD sub-group (chaired by the Irish partner to PROBIOGAS). It would currently appear that national Governance procedures, result in one Government sector being reluctant to take responsibility for or to appear to be taking responsibility for another sections governance concern. This problem may be overcome by the AD industry hosting such a meeting. The invitees would include

- Department of Environment (waste, air, water, climate change, planning sections),
- Department of Agriculture and Food (Animal By-products, infrastructure, pollution control),
- Department of Communications, Marine and Natural Resources (sustainable energy)
- Department for Rural Development and the Gealtacht
- EPA (strategic policy and licensing)
- SEI
- Teagasc (renewable energy resources and nutrient management)

2. Methanogen Ltd will continue to use the knowledge gained during PROBIOGAS in the consultancy work it undertakes, in presentations and in all the advisory opportunities that arise with Government and policy makers (in UK and Ireland)

3. Methanogen Ltd is currently preparing another paper that utilises the information provided by the Danish experts, on how CAD can assist in controlling greenhouse gas emissions, that will then be circulated to relevant policy makers.

4. One of the Irish delegates that attended the PROBIOGAS conference in Denmark in June 2007 has expressed an interest in exploring the possibility of developing a CAD project based on the Irish case study. They have asked Methanogen Ltd to provide a summary of the project potential for the consortium that would develop the project. The consortium are currently looking to develop large scale AD & CAD projects in Ireland and UK. The delegate felt that although the presentation of the Irish case study at the PROBIOGAS conference was not a commercial proposition due the conditions prevailing at the time of the assessment, that because these conditions have now changed that there may be potential in the project.

The impact of PROBIOGAS in Ireland
It is extremely difficult to quantify the impact of the PROBIOGAS project in Ireland. It is certain that during the thirty months of this project, attitudes to AD have changed significantly in Ireland. It could be said that now policy makers are beginning to view AD positively and are interested in how it might help to achieve policy targets in their sector. There are also many more developers wanting to develop AD projects in Ireland. However, the climate for development of both CAD and community/farm AD is still not encouraging.

The PROBIOGAS project has identified and quantified many ways in which AD contributes to energy production, environmental management and agricultural development. Due to the conditions prevailing in Ireland in December 2005 the assessments on the Irish case study CAD do not result in a positive business or socio-economic picture. However, the assessment did highlight where Irish conditions differ from the case studies for the other partner countries, which did have assessment results that would encourage development of a CAD project. If the Irish conditions did change, and some already have, then PROBIOGAS has shown that CAD would be potentially viable in Ireland too.

The PROBIOGAS project has provided the knowledge that informs inter-action with policy makers. This information has played a part in heightening Government's awareness of the value of AD. However, it still remains to be seen whether and how the Irish Government may reward the AD developer for the benefits of AD that are felt by society as a whole, and for which the developer receives no direct benefit.

The PROBIOGAS project has many partners other than the research experts in Denmark. The sharing of experiences of these other partners who have, in the past, also experienced difficulties and barriers to AD development in the own countries, provides inspiration and ideas and is an encouragement to keep on trying to bring about change.

The selected case study in Spain: Region of Pla d'Urgell, province of Lleida

By Joan Mata-Álvarez

The case study is located in a farm located in Vilasana, which is a municipality of Vilaplana, in the region of Pla d'Urgell, within the province of Lleida (see Figure 1). This is a rather dry region, with a low density of inhabitants, dedicated to agriculture and farming.

Figure 7.3. Map of Spain. The case story region is marked by the red circle

This region, Pla d'Urgell has around 320,000 pigs concentrated in 250 of farms, which represent around 4% of the total livestock units in Catalonia. Vilasana, one of the municipalities, with an area of 19.3 km2 and 540 inhabitants, has 15 farms and 26,000 pig livestock units. The largest farm is the one called Porgaporgs, which has been selected as the hypothetical centre to build up a centralised biogas plant. As a whole this farm has around 7000 pigs, distributed as shown in Table10.

Table 7.10. Main farms in the selected site

Livestock	Number of units			Units
	Porgaporcs	Vehi1	Vehi2	
Fattening pigs	4000	1700	1000	produced/year
Sows	600	200	100	stable places
Young pigs (less 20kg)	2400	1000	500	produced/year

In the nearby 2 other relatively large farms have been located with the livestock units indicated in Table 7.10. The total amount of manure produced in these 3 farms is around 57200 t/y. Considering all the pig farms in the area, this amount is increased until 129500 t/y, whereas cattle manure amounts approximately 30000 t/y, poultry around 4700, and other organic waste coming from food industry, almost 4000 t/y. All these wastes and manures gives a total yearly amount of nearly 170000 t/y. This has been the amount used in the calculations, in order to consider the most favourable case.

It seems that a centralised co-digestion plant could help in reducing the cost treatment for industrial wastes, potentially increase the fertiliser value of manures and to decrease the GHG emissions due to manure storage. In addition biogas would be produced which could be transformed into electricity and heat. Unfortunately, heat could not be used for district or industrial heating, because of the distances and the climate conditions. Another added benefit of centralised co-digestion would be the reduction of odours.

Technical description of the proposed co-digestion plant

The centralised anaerobic digestion plant will have a treatment capacity of 167800 tonnes on a yearly basis or 460 tonnes per day. The plant is operated at thermophillic temperatures, which means 52-55 Co. and 15 days retention time. The plant is equipped with 70 Co pre sanitation step, heat exchanging, biogas cleaning facilities, odour control system, storage facility for biogas and CHP plant for heat and power production. From this biomass approx 4,4 mil m3 methane production is calculated. In the CHP plant this energy is converted into electricity and heat, Electricity which may amount to approx. 16000 Mwh is sold to the grid, heat can not be utilized, apart from some heat used for process heating

The manure and organic waste is unloaded in the unloading hall and entered into the pre storage tank. From there it is pumped to the mixing tank in which the biomass is properly stirred and the optimal composition is ensured. From the mixing tank the biomass is pumped to one of the sanitation tanks. It is pumped through the heat exchangers, in order to recover heat from hot, sanitized or digested manure that is simultaneously pumped out of the other sanitation tank or the digesters. By this it is heated to 70 Co and kept inside the sanitation tank for one hour. After that it is pumped through the heat exchangers once again, and into the digesters, where the biogas production takes place. After 15 days in the digester, the now digested manure for the last time is pumped trough the heat exchangers and into the manure storage tank. From the storage tank, the manure is loaded on to trucks and returned to storage tanks at the farms.

The biogas is cleaned in a biogas cleaning tank in a biological process and sent to the CHP plant for conversion into heat and power. This facility is estimated to have a total power production capacity of 1735 kw.

Economic performance of the CAD plant

The calculations are carried out in integrated spread sheet models based on Danish experience. Input data have been provided by University of Barcelona when it comes to defining the case study and input of manure and waste and sales prices for heat and electricity as well as treatment fees for the receipt of organic waste. Costs are calculated in Danish 2005 prices in the first place, and then transformed to Spanish 2005 prices, by using Comparative Price Levels from Eurostat. As the price levels were consumer prices, they were adjusted for variations in VAT. The used interest rate is 5,5 % p.a.

Investment costs have been estimated to be 5,317,000 for the Biogas plant and 1,256,000 for the CHP facility. Taking into account the operating costs, and the sales of electricity at the price of 6,98 €/MWh, the results indicated in the following Table 7.11. are obtained.

Table 7.11. Basic economic analysis of the CAD

ITEM	COST (in thousand €)
Electricity sales	1083
Heat sales	0
Treatment fees	102
Sales in total	1185
Electricity purchase for process	-101
Maintenance	-213
Sand removal	-4
Insurance	-18
Other costs	-31
Staff costs	-101
Premises	-11
Administration	-37
Capital costs	-472
Costs in total	-988
Net result of the plant	197

As it can be seen, a positive result of 197,000 is obtained per year, even considering this much bigger size of the CAD. If transportation costs which amount around 595,000 €/y are considered, which represents a much more realistic approach, the net cash-flow comes down to -400,000 €/y, which makes the feasibility not possible.

A further analysis considering (integrating) the externalities showed that the numbers were very difficult to turn positive. However, a recent reglamentation issued in Spain has doubled the electricity price (a claim issued also from this project), which has dramatically changed the situation. Even without considering the externalities, plants can present a positive cash-flow, which, of course, poses in a competitive situation biogas technology and thus CAD. The extensive and detailed analysis of the externalities implicated in the agro-industrial wastes digestion carried out in this project, will of course contribute to the better knowledge of the process and to appraise in a holistic way the advantages of CAD. Thus, summarizing, the estimated cash flow of the CAD was around –400,000 €/y in the previous situation, whereas now, it can be estimated around +600,000 €/y. As the overall investment is 6,650,000 €, the payback time of the plant is around 10 years. Although this figure is still too high for such a plant, if solutions are seeked to use the excess heat, it will be possible to decrease this time and make fully attractive the CAD solution.

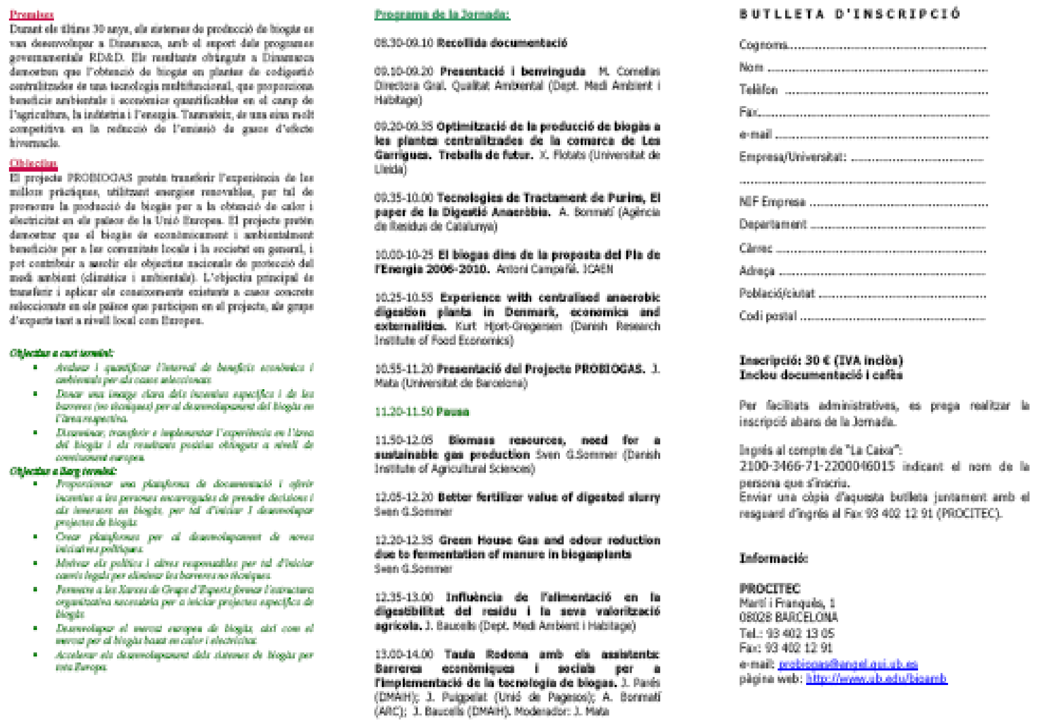
Collaboration with TGN

One of the main activities in PROBIOGAS was the establishment of TGN of 31 members and the introductory workshop on 15th of June 2005 arranged in Barcelona.

Figure 7.4. PROBIOGAS first meeting in Barcelona

Due to the location of the venue the farmers were represented in this meeting only by the farmer's organizations. Many of the 45 participants were officials from regional government offices and companies interested in the field of biogas. Danish experts' presentations raised interest among the participants and intense debate and exchange of opinions took place. Two main barriers were identified: a) the lack of confidence in the centralised co-digestion concepts and their ability to solve problems with surplus manure, b) The low prices for electricity produced on biogas

TGN and specially two members Teresa Guerrero from Agencia de Resdius de la Generalitat de Catalunya, Mr. Pons and Mr. Porta, from PORGAPORGS farm, were very helpful in the data collection process in order to asses the economic and environmental effects of centralised co-digestion for the selected case. The location of the selected case was Vilasana, a village of Pla d'Urgell in Catalonia, Spain. A set of data templates was collected with the help of the local authorities, of Generalitat (Agencia de Residus) and of local farmers, was elaborated and sent to the Danish experts for development.



Premisses

Durant els últims 30 anys, els sistemes de producció de biogàs es van desenvolupar a Dinamarca, amb el suport dels programes governamentals RD&D. Els resultats obtinguts a Dinamarca demostren que l'obtenció de biogàs en plantes de codigestió centralitzades és una tecnologia multifuncional, que proporciona beneficis ambientals i econòmics quantificables en el camp de l'agricultura, la indústria i l'energia. També és una eina molt competitiva en la reducció de l'emissió de gasos d'efecte hivernacle.

Objectius

El projecte PROBIOGAS pretén transferir l'experiència de les millors pràctiques, utilitzant energies renovables, per tal de promoure la producció de biogàs per a la obtenció de calor i electricitat en els països de la Unió Europea. El projecte pretén demostrar que el biogàs és econòmicament i ambientalment beneficiós per a les comunitats locals i la societat en general, i pot contribuir a assolir els objectius nacionals de protecció del medi ambient (climàtics i ambientals). L'objectiu principal és transferir i aplicar els coneixements existents a casos concrets seleccionats en els països que participen en el projecte, als grups d'experts tant a nivell local com Europeu.

Objectius a curt termini:

- *Analitzar i quantificar l'interval de beneficis econòmics i ambientals per als casos seleccionats.*
- *Donar una imatge clara dels incentius específics i de les barreres (no tècniques) per al desenvolupament del biogàs en l'àrea respectiva.*
- *Disseminar, transferir i implementar l'experiència en l'àrea del biogàs i els resultats positius obtinguts a nivell de coneixement europeu.*

Objectius a llarg termini:

- *Proporcionar una plataforma de documentació i oferir incentius a les persones encarregades de prendre decisions i als inversors en biogàs, per tal d'iniciar i desenvolupar projectes de biogàs.*
- *Crear plataformes per al desenvolupament de noves iniciatives polítiques.*
- *Motivar els polítics i altres responsables per tal d'iniciar canvis legals per eliminar les barreres no tècniques.*
- *Permetre a les Xarxes de Grups d'Experts formar l'estructura organitzativa necessària per a iniciar projectes específics de biogàs.*
- *Desenvolupar el mercat europeu de biogàs, així com el mercat per al biogàs basat en calor i electricitat.*
- *Accelerar els desenvolupament dels sistemes de biogàs per tota Europa.*

Programa de la Jornada:

08.30-09.10 **Recollida documentació**

09.10-09.20 **Presentació i benvinguda** M. Comellas Directora Gral. Qualitat Ambiental (Dept. Medi Ambient i Habitatge)

09.20-09.35 **Optimització de la producció de biogàs a les plantes centralitzades de la comarca de Les Garrigues. Treballs de futur.** X. Flotats (Universitat de Lleida)

09.35-10.00 **Tecnologies de Tractament de Purins. El paper de la Digestió Anaeròbia.** A. Bonmatí (Agència de Residus de Catalunya)

10.00-10.25 **El biogas dins de la proposta del Pla de l'Energia 2006-2010.** Antoni Campañá. ICAEN

10.25-10.55 **Experience with centralised anaerobic digestion plants in Denmark, economics and externalities.** Kurt Hjort-Gregersen (Danish Research Institute of Food Economics)

10.55-11.20 **Presentació del Projecte PROBIOGAS.** J. Mata (Universitat de Barcelona)

11.20-11.50 **Pausa**

11.50-12.05 **Biomass resources, need for a sustainable gas production** Sven G.Sommer (Danish Institute of Agricultural Sciences)

12.05-12.20 **Better fertilizer value of digested slurry** Sven G.Sommer

12.20-12.35 **Green House Gas and odour reduction due to fermentation of manure in biogasplants** Sven G.Sommer

12.35-13.00 **Influència de l'alimentació en la digestibilitat del residu i la seva valorització agrícola.** J. Baucells (Dept. Medi Ambient i Habitatge)

13.00-14.00 **Taula Rodona amb els assistents: Barreres econòmiques i socials per a l'implementació de la tecnologia de biogas.** J. Parés (DMAH); J. Puigpelat (Unió de Pagesos); A. Bonmatí (ARC); J. Baucells (DMAH). Moderador: J. Mata

BUTLLETA D'INSCRIPCIÓ

Cognoms...

Nom ....

Telèfon ....

Fax...

e-mail ....

Empresa/Universitat: ....

....

NIF Empresa ....

Departament ....

Càrrec ....

Adreça ....

Població/ciutat ....

Codi postal ....

Inscripció: 30 € (IVA inclòs)
Inclou documentació i cafès

Per facilitats administratives, es prega realitzar la inscripció abans de la Jornada.

Ingrés al compte de "La Caixa":
2100-3466-71-2200046015 indicant el nom de la persona que s'inscriu.
Enviar una còpia d'aquesta butlleta juntament amb el resguard d'ingrés al Fax 93 402 12 91 (PROCITEC).

Informació:

PROCITEC
Martí i Franquès, 1
08028 BARCELONA
Tel.: 93 402 13 05
Fax: 93 402 12 91
e-mail: probiogas@angel.qui.ub.es
pàgina web: http://www.ub.edu/bioamb

Figure 7.5 PROBIOGAS leaflet in Spanish

TGN meeting were frequent and some pressure was exerted to increase the electricity price, one of the main claims of farmers during the meeting. It was agreed with Mr. O. Bartomeu to wrote a letter with some basic calculations to make it patent the savings on CO_2 emissions derived from CAD. In this calculations it was claimed that the internalization of the CO_2 costs would increase the electricity price in around 4-5 €/MWh. As can be seen from the exposition of the previous section an higher increase has been achieved (around 7 €/MWh).

Finally TGN members help in the distribution and completing a questionnaire to define the non technical and other barriers that could impede the implementation of biogas technologies in Spain, elaborated as a multiple choice template. Basically the barriers identified in WP3 were also identified in this questionnaire, that is, electricity low price, heat utilization not being an option in the respective region and lack of incentives for farmers to national restrictions on waste application and on digestate utilization.

Detailed description of dissemination activities

First dissemination activity was the meeting hold in Barcelona on 15 May. It was attended by 45 people, among which 20 members of the TGN. In that meeting representatives of the farmers were present (cooperatives) which expressed their opinions on the feasibility of CAD given the conditions of that moment. A web page was set www.ub.edu/bioamb/probiogas, as a mean of diffusion of the activities of PROBIOGAS in Spain. At the beginning, and as a result of the dissemination activities, around 300 visits were achieved. Then, the rate decrease and at the end of the project around 550 visits have been registered. Considering the rather poor feasibility of the project at the beginning this was not a bad number.

On the other hand, a number of visits have been paid, to different regions of Catalonia, specially in the region of Baix Camp (Reus) and also in Girona (Sant Feliu Guixols) to study the feasibility of a codigestion with sewage sludges. Two small presentations of the project were carried out in this locations. An interesting visit was carried out at the

Figure 7.6. Visit to Juneda. Unloading pig manure

CAD in Juneda (Spain) where centralised digestion of piggery waste is carried out. The problem of this plant is that they are drying the digestate to be spread on the field, with natural gas. In this way they get a good price for the electricity they generate. Of course this seems not a very good environmental option and discussions on this aspect took place. Enclosed there are 2 pictures of the visit (Figures 4 and 5), with a small group.

Figure 7.7. Visit to Juneda. Digesters

Other visits were made to other regions in Spain, for instance to Valencia and San Sebastian. In this meetings the situation on the region was discussed and contacts were established to keep an open channel for dissemination. Also some trips to see and discuss dissemination activities were made in Montpeller and also to Amsterdam.

Finally a number of meetings (congresses, workshops, etc.) were attended related with the agroindustrial wastes. In all of them a poster of the PROBIOGAS project was posted. Table 7.12. lists these events.

Table 7.12. Congresses, where the PROBIOGAS project poster was displayed

Event	Place	Dates
I PROBIOGAS meeting	Barcelona	15 may 2005
Ii congreso sobre residuos biodegradables y compost	Sevilla	20-21 october 2005
Miniforo iberoeka	Oviedo	20 april 2006
La biometanización: valorización de los residuos a través de la producción de biogás	Madrid	17 and 18 june 2006
Biological waste management from local to gloval	Weimar	13-15 september 2006
The seven international symposium on wste management problems in agro-industries	Amsterdam	27-29 september 2006
Expoaviga 2006. Programa de deyecciones ganaderas	Barcelona	20 october 2006
Segunda reunión de la red de compostaje española	Valencia	25-27 october 2006
Biogas from anaerobic digestion of the organic fraction of msw and other co-substrates"	Milan	7-10 may 2007
PROBIOGAS final meeting (see program in attached table)	Barcelona	23 may 2007

In the last meeting in Barcelona, the final report was presented. There was a poor attendance, much less than expected. The reason of this may be motivated by the rather negative results of the National assessment report in Spain. However, the discussion among the attendees was very interesting and it was evidenced that without any change in the legislation the CAD in Pla d'Urgell was not feasible. There was also some news about the close issue of a much more favorable price for electricity. It was stressed the importance of co-digesting other agro-industrial wastes, because of its high biodegradability and thus, biogas potential. In additional, important savings are achieved at using the same infra-structure. Industry should be aware of this potential and efforts to disseminate biogas technology to the agro-industrial sector should be carried out.

Figure 7.8. Poster of the Final meeting in Barcelona

The impact of PROBIOGAS

No success stories can be told, as no success of the planned plant was evidenced until the very end end of the poject (see above). In any case, some positive actions can be pointed out: For instance the interest of the farmer Mr. Porta. However, from the very beginning, the farmers

manifested their skepticism on the project feasibility, until dramatic changes on the electricity price policy took place. Of course, the main barrier identified, which was the non feasibility of CAD due mainly to electricity cost, prevented the success of the dissemination activities. Even considering (integrating) the externalities, the numbers showed the negative cash flow for the case study, which was quite representative of the Spanish situation. However, as mentioned, the situation has changed after the project final meeting, due to the publication of a new legislation favoring the electricity price for such applications. Use of heat could also favor the feasibility, although in a limited basis.
Thus, until now, the impact of PROBIOGAS project has been quite limited, due to the reasons mentioned. In any case, main impact has been the draw the attention on many externalities, which make the CAD process more interesting from an environmental point of view. This is also important, because, even with the new electricity price, still the project is not quite profitable from the economic point of view. The inclusion of externalities could change the perspective, and thus it is important to continue working on this direction.

What now?
The main ongoing activity is the next I Congreso Español de Gestión Integral de Deyecciones Ganaderas, (First Spanish Congress of Management of cattle dejections), which will be held in Barcelona in April 2008. This National Congress, of which the Spanish coordinator of PROBIOGAS is member of the Scientific Committee, will join all the main actors in Spain, including the TGN, and will examine the situation of the management of cattle wastes in Spain. There results of the PROBIOGAS project will be presented together with some new insights coming from the new electricity price. Another event to present similar results will be the 3rd Meeting of the Composting Spanish Network, which will take place also in Barcelona (it is a nation-wide meeting). Again, the Spanish coordinator of PROBIOGAS is member of the Scientific Committee, and a presentation similar to the one in the previous mentioned event will be also carried out. Of course attention will be paid on the organization of meetings with the participation of farmers (in the first one mentioned here, they will be invited). In all of these meeting the importance of externalities will be highlighted.
The results (conclusions) of these and other relevant events will be posted in the web page that will be active for the next two years.

The selected case study in Belgium: Sprimont, province de Liège, NE of Wallonia

By Fabienne Rabier and Gaëlle Warnant

The chosen area in the Belgian case is located in the Province de Liège, one of the 5 Provinces of the Walloon part of Belgium (Northeast of Wallonia)

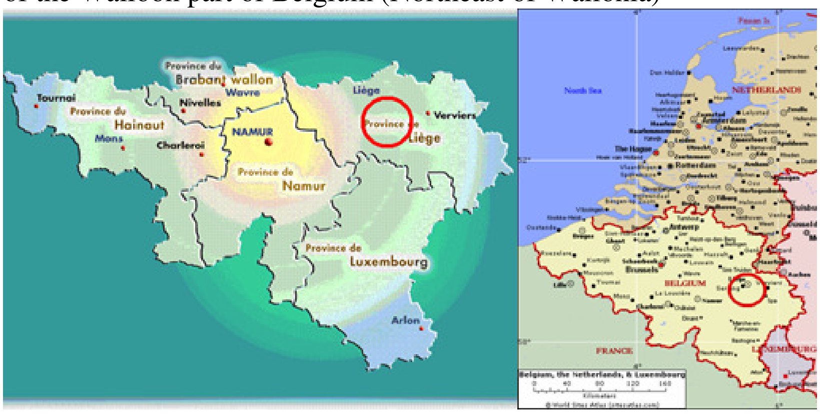


Figure 7.9. Walloon part of Belgium and its provinces. The case study is marked by the red circle

The chosen area is specialised in milk production with more than 35,000 cows. Additionally, some large pigs and poultry farms are also located in this area. 40 farms are included in the case study: 20 in the Commune of Sprimont and 20 in the commune of Limbourg. The total agricultural area where the manure is spread is about 2,200 ha. The main crops in this area are fodder crops as maize and grass. The following tables summarised the quantity of agricultural manure which can be collected among the 40 farms. The manure will not require processing before digestion.

Very few industries are interested in a biogas project, as costs for present waste treatment are not very high. A big part of the waste is used to feed animals (paid by farmers). The cheese industry runs a project for anaerobic digestion of the lactoserum but only on an individual scale (just the industry alone) and is not interested in co-digestion with other products.

They are several potential users of the heat. Other financial gains should be obtained by the Green Certificates that the biogas unit could get. The calculation of the number of the Green Certificates is made by the Walloon Commission for Energy.

For the Belgian case study, 2 projects within the same region are presently studied

1) Project of the town of BILSTAIN
2) Project of the town of SPRIMONT

In order to get enough biomass per day feeding the digester, it was chosen to merge the 2 cases and pool the data. Because of its localisation, the small town of Sprimont is the chosen site for the virtual plant

Brief description of development process involved and ownership
Two small projects of agricultural biogas units are located in the region of Pays de Herve, in ***Bilstain*** and in ***Sprimont***. Both were initiated by farmers interested in better manure management in term of storage capacity and quality as many farms are old with storage capacity and tanks not adapted or not in conformity with the new nitrogen legislation (6 month capacity storage).

Project of Sprimont: the idea came up in 2003 after discussions between farmers and a private media company (EVF). A meeting to inform the farmers about biogas production was held in the commune. 24 farmers took part at the meeting and showed some interest to this project. As it was first planned to process only agricultural manure, no food industry was contacted.
Other meetings were held to collect data from farmers but also to convince local authorities who were afraid of traffic nuisance of the cartage.
A pre-feasibility study was carried out by the "biomethanation facilitator" of the Walloon Region, ensuring a total support of local authorities.

In 2004, as the pre-feasibility study expressed favourable opinion about the project, a feasibility study was ordered to a consultancy agency. The latest assessment and study (2006) showed that the profitability could not be reached in the present form of the project. Nevertheless the feasibility study of Sprimont unit has shown the project would not be profitable in a reasonable time. New developments in this project may make evolve the latest conclusion.
Project of Bilstain: the first step was taken in 2004 at a conference held in the town about renewable energies and opportunities of diversification for agriculture. The "biomethanation facilitator" presented the concept of AD.
A visit in Luxembourg was organised to see a biogas plant processing agricultural wastes. Farmers of the town as well as local authorities were enthusiastic and after several meetings 8 farmers decided to set up a society with unlimited responsibilities. The idea was to keep the size

of the project as small as possible without including food industries in order to avoid an environmental impact assessment. This kind of study is compulsory for unit treating more than 50 Ton/day in inhabited area and for unit treating more than 100 Ton/day in other zone. As for Sprimont, the pre-feasibility study supported by the Region (with facilitator intervention) pointed out a favourable opinion. In 2005, the farmers formed them-selves into a society with unlimited responsibilities which paid for the feasibility study. This study carried out at the present time is still in progress.

For both projects it is planned that the unit would be managed by farmers through a cooperative of manure management. The unit would belong to farmers, private companies and regional authority. In both cases different aspects like processing by-products from food industries and energy crops have to be taken into account as well as externalities. Considering the potential of manure, the number of food industries in the area and the motivation of farmers and local authorities it was decided to choose both projects, collect the data from the two of them and merge them to ensure sufficient amount of manure in one single unit and include wastes from food-industries that were located in the area.

General aspects of the area

The chosen area is located in the Province of Liège.

<u>Soil & subsoil type</u>
Silty soil with more than 15% coarse elements (>2 mm). Cambic horizon. Good draining

<u>Population density</u>
Population density of the Province Liège: 267,7 inhabitant /km²
Town Sprimont: 172,5 inhabitant /km²
Town Limbourg (Bilstain): 227, 8 inhabitant /km²

<u>Road network</u>
Road network is dense: the whole region is well served by roads and transportation network:

- Access to highway are close to the town: Sprimont has a direct access to the main North-South road (Liège-Luxemboug E25): the access to the main East-West road (Aachen-Liège E40) and interchange of Liège is 25 km far from Sprimont.
- Main roads, and local roads are in good conditions
- Small roads between farms are narrow and more winding but in good condition.

----- Borders of communes __ Highways, __ Regional roads, o Access to highway

Figure 7.10. Road network in the region of Pays de Herve (East of Wallonia)

Main activities:
Agriculture : cattle breeding for milk production, some pig and poultry breeding, grassland, arable crops, orchards,…
Small and medium size food industries: cheese production, dairy products, fruit processing factories (syrup, cider), meat processing factories and small firms making regional specialties (family firm)
Industry: previously the region had an important mining activity (coal mines) but all the coalmines were closed. Now the main industries are located in the outskirts of Liège and along the river Meuse.

The area of the site: potential/ material to be processed

Agriculture
The chosen area is specialized in milk production with more than 35000 cattle. Additionally, some big pigs and poultry breeders are also located in this area.
40 farms are included in the Belgium project: 20 in the Commune of Sprimont and 20 in the commune of Limbourg.
The average size of the farms is 55,2 ha which is bigger than the mean value observed in Wallonia (44,1 ha).
The total agricultural area where the manure is spread is about 2 200 ha.
The main crops in this area are fodder crops as maize and grass. Within the 40 farms studied agricultural land distribution is:
88,6 %: grass
8,5%: maize
2,9%: winter wheat

The following tables summarized the quantity of agricultural manure which can be collected among the 40 farms. The manure will not require processing before digestion.

Table 7.13. Manure collected from farms (m³/per year)

Animal type	Liquid manure [m³/year]	% dm
Dairy cattle	43 236	7.1
Pigs	8 056	10.2

Table 7.14 Solid manure collected from farms (ton/per year)

Animal type	Solid manure [T/year]	% dm
Cattle	4 651	27.8
Horses	180	27.8
Broilers	2 268	55

The possibility to get energy crops to feed the digester was also studied. The table 7.15 shows the quantities of energy crops which could be grown by farmers on the area.

Table 7.15. Energy crops collected from farms (ton/per year)

Energy crop type	Amount [T/year]	% dm
Corn	1 922	30
Grass silage	885	30

Agro-food industries

Main production of the region are dairy products (milk transformation, butter, cream), cheese production, fruits processing (syrup, jam, cider), cereals and starch transformation.

41 industries were listed within the zone but only 22 could have by-products suitable for anaerobic digestion. 11 replied to the questionnaire. Wastes that are taken into account come from 7 industries. Waste products with dry matter < 2% have been excluded from the biomass input. No by-product or organic waste will require processing before digestion.

Table 7.16. Identified by-products taken into account for the case study

Type of organic waste	Amount (T or m³/year)	Dry matter (%)
Waste water from milk industry	800 tons	6
Waste water from cheese industry	5 430 m³	7
Lactoserum from cheese industry	8 000 m³	5
Fruit pulp	1 220 tons	30
Appel pulp (from cider factory)	200 tons	7
Fruit pits	150 tons	85
Strachy products	800 tons	7

Comments:

Very few industries are interested in biogas project because:

- cost for present waste treatment are not very high;
- a big part is already used for animal feeding and thus sold to farmers;
- one cheese industry has a project for anaerobic digestion of the lactoserum but to an individual scale and is not interested by co-digestion with other products.

The biogas plant: by-products produced

<u>Biogas utilisation</u>

The proposed use for biogas: conversion to heat and electricity (CHP). From the feasibility study of the project, the distribution is:

- Energy losses: approx. 15%
- Electricity: approx. 35% among which
  - self-consumption: 3.5%
  - injected to the grid: 31.5%

For the electricity injected to the grid the average price for electricity sale is: 25 €/ MWh él.

- Heat: approx. 50%
  - self-consumption by the plant: 20% (for sanitation and heating the digester)
  - other heat users: approx. 30%

For heat sales the average price is 30 €/MWh th., but it varies strongly depending on the case.

They are several potential users for the heat:

- local museum;
- sports hall;
- school;
- communal buildings;
- greenhouses ;
- senior home.

Different scenarios are still studied:
1) heating all the potential buildings require 3 separated district heating systems
2) heating greenhouses and sports hall require one district heating system

Other financial gain should be obtained by the Green certificates the biogas unit could get. The calculation of the number of the green certificates is made by the Walloon Commission for Energy.

Digested manure
Liquid and solid fraction will not be separated. The digestate will be used on grassland and arable crops as a fertiliser. The amount of digestate will share between the farms that supply the digester with farm effluents (% of digestate following a % a feedstock supplied). Farmers using digestate from co-digestion need a special licence and analysis of digestate have to be regularly carried out by a registered laboratory. Costs of analysis are in charge of farmers.

Transportation
The digestate will be returned to the farms in the same trip as collecting manure. The vehicles used for transportation for each purpose would be farm trucks, trailers or tankers. In economic assessments however, trucks with 30 tonnes load are used, as a large capacity is crucial in minimising transport costs

The food industries are within a 40 km radius of the site and the most distant is 37 km away from the chosen site, but the average distance is 25 km.

Table 7.17. Transport distances

	Average distance (km)	
	Distance farms to unit	Distance food industries to unit
Sprimont site	15,6	25

Farming issues

Storage requirement regulation: 6 months capacity storage from 1 January 2007.
Implementation of Directive 91/676/EEC on nitrates from agricultural sources.
The area is partly classified as "vulnerable zone" where special measures for fertilisers application are applied. Sprimont is just on the boundary of this region and none of the farms of the project is in the vulnerable zone.
A sustainable management of nitrogen program is implemented. Amount and period for fertilization are regulated according this program.

Table 7.18. Permitted organic N application on different land types

Amount of organic n	Grassland	Arable land
Normal zone	210 kg /ha	120 kg/ha
Vulnerable zone	210 kg/ha	80 kg/ha

Table 7.19. Prohibited periods of fertilisation

Period when fertilisation is prohibited (depending on the type of manure and soil cover		
	Fast fertilising effect (slurry, poultry droppings	Slow fertilising effect (solid manure, compost)
Arable crops	From october to february	
	From july to september except if:	From july to september except if:
	Winter cereals	Winter cereals
	Crops trapping nitrogen	Crops trapping nitrogen
	Straw incorporation	Straw incorporation
Grassland	From september to november	

If wastes or other biomass external to the farms are to be processed into the digester, all the farmers need special authorisations from the Walloon Office of wastes (OWD).
A comprehensive analysis of soil must be carried out before digestate could be first spread on land: % organic matter, minerals, and heavy metals. Cost of soil analysis: 100 € per sample which means about 2 000€ for a farm.
Analyses of the digestate must be carried out twice a year, this represent in average 1500 € /year.
Need of analyses of every external biomass included in the digester.

Regulatory environment

National & EU Regulations to be met
Licences/permissions to be obtained: planning permission from regional authorities (General Direction of Land Planning): the unit site is located in a zone of economic or industrial activity (formerly a quarry site).
Waste license from Walloon Office of Wastes if products from food industries are processed.
Licence to generate green energy and obtain Green certificates (from Walloon Commission for Energy -CWAPE).

Other issues related to CAD

Energy policies:

In Belgium the **Green Certificate system** is applied in order to support the production of “green electricity”.
A green certificate is a transferable certificate issued to producers of green power for a number of kWh generated which is equal to MWh_e divided by the carbon dioxide saving rate.
The carbon dioxide saving rate is calculated by dividing the carbon dioxide gain achieved by the system under consideration by the carbon dioxide emissions of the traditional reference electric system (steam and gas turbine), the emissions of which are defined and published annually by the Walloon commission for Energy. This carbon dioxide saving rate is limited to 1 for generation units producing over 5 MW, and 2 below that limit.
The carbon dioxide emissions are those generated by the green power generation as a whole and include fuel production, emissions during combustion if applicable, and waste processing if applicable. In the case of centralised co-digestion transportation of external wastes or fuel consumption for energy crops are taken into account and penalize the profit making of the biogas unit (less green certificates are obtained).

The system poses higher risk for investors and long-term, high cost technologies (as biogas plant) are not easily developed under such a scheme. However new decisions have just been taken to favour biomethanisation projects in agricultural sector as for biogas projects the price of **Green Certificates will be guaranteed at a minimum price of 65 €/GC for a period of 15 years** (instead of 10 years before).
At the end of 2006 the average value was 90.8€/GC but it could diminish in the future (around 80€/GC).

The costs of the connection on the electricity grid are very high and are totally in charge of the owner of the plant: around 25 000 to 50 000 € (medium voltage) for a farm unit.

Support available

Different sources of financial support can be solicited for biomethanisation project but some subsidies depend on the status that the project initiators will adopt. Some of these aids are:

- the first pre-feasibility study carried out by facilitator is free
- a grant from regional authorities for consultancy: maximum 75% of consultancy fee (with a maximum of 12 500€ subsidies)
- tax exemption on real estate (property) tax

Special subsidies (depending on owners/shareholders)

- If *local authorities* are among the owners the Commune can apply for special financial support (investment in renewable energies for public buildings).
- If project managers are *private firm or with a commercial activity*.
- If project managers form an *agricultural cooperative*, subsidies from the Ministry of agriculture are available following some conditions. There are 3 different kinds of financial support:

1) Subsidies on the interest rate on investment or loan (5% maximum), the rest of interest rate in charge of the borrowers is around 3%.
2) Public guarantee
3) Subsidies on capital if farmers don't call for a loan.

Tax deductions on investment for energy savings for industrial, commercial or agricultural companies. Tax deduction can reach 40% and can be applied for "energy audit" and CHP systems.
Most of the subsidies or financial support programs can not be drawn concurrently and depends on the status of the projects managers. For Sprimont, the farmers have formed a agricultural cooperative and would normally receive financial supports from private and public participation.

Agencies, representative associations, supportive of/assisting the project: "biomethanisation facilitator", local authorities, FWA (Walloon union of farmers).

Public relations

At the beginning, the project has been initiated by local farmers. The mayor of the town and the local authorities have supported the project since the beginning.
Citizens of Sprimont have heard about the project and they have shown no reluctance until now. Nevertheless the biogas plant project has not been explained yet to the local population and they have not been consulted yet.
Inquiries of the neighbourhood have to be made before the building starts (once planning permission is obtained). Some people may be opposed to the project fearing that the plant would cause nuisances such traffic of trucks, noise, odours…
Stakeholders and local authorities are aware that it is necessary to inform local people about the benefits of biogas production, as well as, the immediate consequences for them.

Agricultural papers, local television and radio will spread any further development of the projects.

Technical description of the proposed co-digestion plant

The biomass resources in this project consist from manure and organic waste.

Table 7.20. Composition of biomass resources

Type of biomass resources	Tonnes
Cattle manure	47887
Pig manure	8056
Other manure : horses	180
Other manure : broilers	2268
Organic waste	16600
Total	74991

Liquid manure is transported to the plant in vacuum tankers with a 30 tonnes load. Solid manure and deep litter are transported on trucks with a 20 tones load.
It is assumed in the study that organic wastes are delivered at the plant by the waste producer.
From this biomass approx. 1, 5 million m^3 CH_4 is produced according to the calculations presented in chapter 4.
As presented in the part 2-5, in the CHP plant, this energy is converted into electricity and heat. Electricity production, which may amount to approx. 5,5 mil KWh is sold to the grid, and heat production, which may amount to 7,9 mil KWh of which only 2,9 MWh can be sold for heating purposes.

The centralised anaerobic digestion plant will have a treatment capacity of 75000 tonnes on a yearly basis or approx 200 tonnes per day. The plant is operated at thermophillic temperatures, which means 52-55ºC. and 15 days retention time. The plant is equipped with 70 C^o pre sanitation step, heat exchanging, biogas cleaning facilities, odor control system, storage facility for biogas, and CHP plant (800 kW_e) for heat and power production. Figure 3.1 shows a diagram of the plant.

The manure and organic waste is unloaded in the unloading hall and entered into the pre storage tank. From there it is pumped to the mixing tank in which the biomass is properly stirred and the optimal composition is ensured. From the mixing tank the biomass is pumped to one of the sanitation tanks. It is pumped through the heat exchangers, in order to recover heat from hot, sanitized or digested manure that is simultaneously pumped out of the other sanitation tank or the digester. By this it is heated to 70ºC and kept inside the sanitation tank for one hour. After that it is pumped through the heat exchangers once again, and into the digester with a capacity of approx. 3100 m^3, where the biogas production takes place. After 15 days in the digester, the now digested manure for the last time is pumped trough the heat exchangers and into the manure storage tank. From the storage tank, the manure is loaded on to trucks and returned to storage tanks at the farms.
The biogas is cleaned in a biogas cleaning tank in a biological process and sent to the CHP plant for conversion into heat and power.
Odour emissions from the plant is controlled by sucking away air from the unloading hall, the pre storage and mixing tanks, and cleaning it in a biological odour filter.

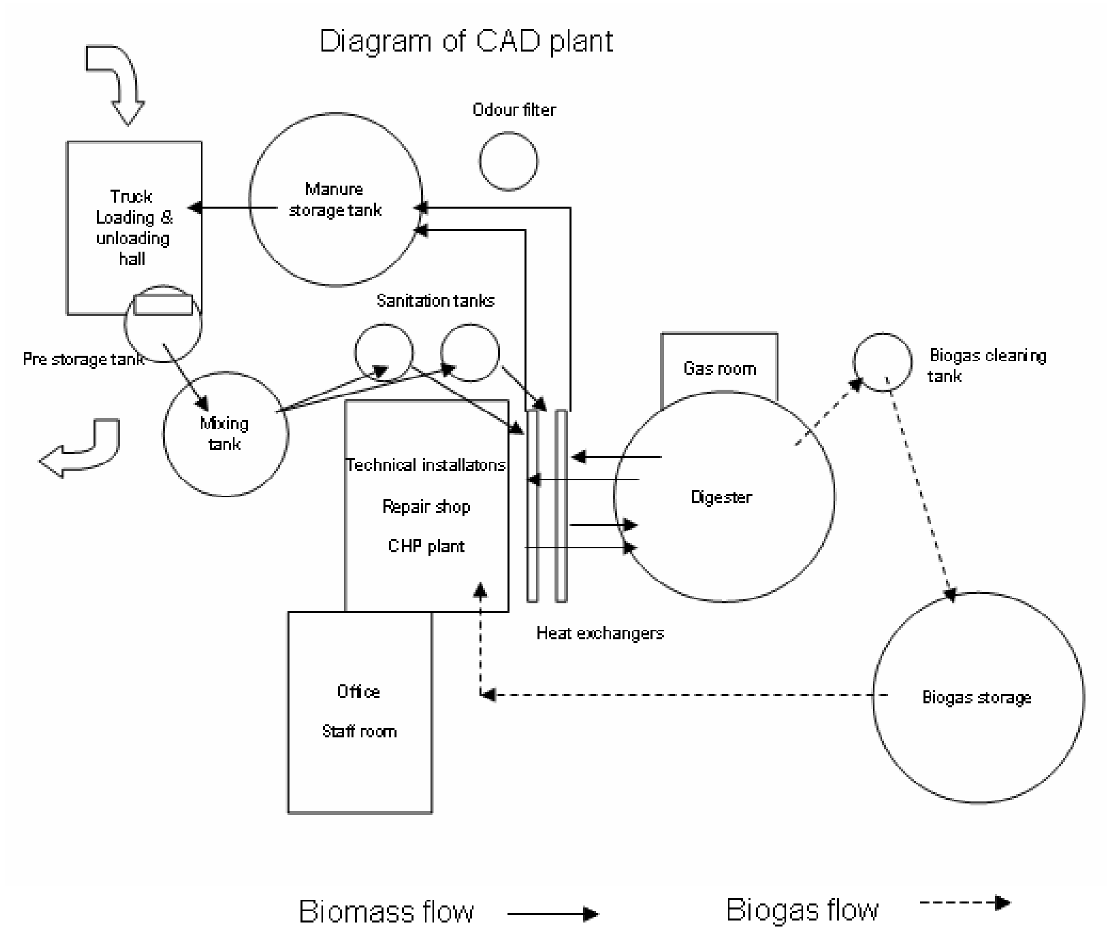


Figure 7.11. Diagram of the CAD plant

Collaboration with the Target Group Network

At the early stage of the project, a list of possible members of the TGN was made. This list was drawn up from the list of the members of the "Club methanisation". This club was created in 2003 in order to promote the production and the utilization of biogas in the Walloon part of Belgium. The Club methanisation was a working group which included various actors active in the field of biogas production: consultancy offices, representatives of local government or public services, universities, research centre, etc. The main roles of this working group were:

- to advise and guide the political and administrative decisions;
- to find solutions to problems among the sector;
- to collect and exchange information.

In addition to the members of the "Club methanisation", farmers, representatives of food-industries, additional environmental or waste agencies and decision makers were added to form the TGN.

Finally the TGN was made of 46 people representing different elements of the biogas chain. The following table summarizes the different organizations represented in the TGN.

Table 7.21. Description of the TGN

Activity	% of the TGN members
Food industries	4
Energy trader	4
Research center and universities	7
Non profit making association	13
Consultancy office	15
Farmers and farmer union	24
Regional authorities	33

It must be said that in the course of the project, new members were added in the target group. As new developments in the field of biogas or new projects have been initiated, some people were interested to join the group in order to be kept informed about the results and potential effects of the study. At present (July 2007), around 70 members form the TGN in Wallonia.

After the constitution of the TGN, some members were solicited to give information or comments about specific question which occurred during the project.

For example, since the beginning of the project, some members of the TGN were involved in the selection of the Belgian case study. Propositions made by CRA-W were back up by the TGN.
Some members of the TGN were also requested to approve the list of the non technical barriers, to give comments and suggestions to improve it.

To collect data concerning the chosen case in the Province de Liège, the farmers who were members of the TGN were contacted in order to prepare meeting in the area with all the farmers that could be involved in the local biogas project. The farmers representatives of both projects helped us to keep in touch with local farmers and to promote the project among the sector. In total 40 farms participated to the data collection.

About the energy aspects of the project and the selection of the plant localization, a consultancy office member of the TGN gave information about the feasibility studies of the two different projects initiated in the area. This allowed to choose the best location for the plant and to estimate the proportion of heat which could be used.

Globally since the beginning of PROBIOGAS activities, the communication between the Belgian partner and the TGN has been pretty good. Starting the project by forming a TGN has helped to solve problems during the project, and to get information from professionals of the biogas chain rapidly.

Dissemination activities
The dissemination activities have started at the beginning of the project with the constitution of the national target group by explaining the CAD concept and the aim of the PROBIOGAS project. Throughout the project, information were given to the TGN to keep them informed about the project status. PROBIOGAS newsletters, translated into French, were also sent to all members.

After the National assessment report was finished, the results were disseminated among the TGN or made available to all people interested in having them. The results were presented in two different ways.

First, 2 presentation sessions were held with farmers of the area (one in Sprimont and one in Bilstain). The main results of the project were stated and explained, enhancing more specifically the agricultural aspects and farming issues. Moreover, in collaboration with the General Direction of Agriculture of Wallonia, a special presentation session was held for the members of TGN. Results and all explanation about the socio-economic calculations were given and a comparison between the Belgian and the other cases was also made. This meeting was also the opportunity to discuss about general situation of biogas in the Region and to make status of the current projects. The table 7.22 presents the dissemination activities.

Table 7.22. Activities during the whole project – Belgian partner

Presentation of the project and constitution of the TGN	Translation of the leaflet, fact sheet to present the cad concept, mail and phone calls to members of TGN	Probiogas leaflet (into French version) Fact sheet "what is the cad concept?" French version
PROBIOGAS introduction meeting (presentation of the project and of the method developed by the danish experts, role of the TGN and future activities)	Invitation to TGN, organization of the meeting, preparation of the agenda, presentation, translation of the danish presentation and copies of all documents.	Presentations for the meeting french version (powerpoint presentations)
Newsletters (presentation of news from the 6 participating countries, important facts or events for the development of the biogas production)	Translation of the PROBIOGAS newsletters sent to TGN members.	3 newsletters into french version
State of the project (giving information about the progress of the project)	Mail to inform members of TGN of the progress of the project. Mail to inform members of TGN about the end of the projects and the availability of the national assessment report	Copy of letters sent to TGN.
Meetings with farmers (presentation of the PROBIOGAS results)	Translation of the national report. Invitation to farmers, organization of 2 presentation sessions of the results.	National assessment report (french version) presentations of the results (ppt presentations french version)
Meeting with the TGN (presentation of the PROBIOGAS results)	Invitation to members of TGN, organization of a meeting: presentation of PROBIOGAS results of the belgian case and results of all cases + 3 presentations from external speakers about biogas situation in wallonia	National assessment report (french version) presentation of PROBIOGAS results (belgian case + other case-studies) (ppt presentations french version)
Participation in the workshop "future of biogas in europe iii" in denmark where the belgian situation and results of PROBIOGAS project were presented . Participation in the project final meeting.	Preparation of the workshop: writing an article about the belgian case study + oral presentation (ppt presentation). Information in the valbiom newsletter about the PROBIOGAS results and the international workshop.	Paper for the proceedings + oral presentation for the workshop: "environmental and socio-economic analysis of the setting-up of a centralised co-digestion plant in the walloon region-belgium". Links to the workshop proceedings on valbiom website.
Article in the newspaper of the farmers unions (disseminations of the results among farmers sector)	Redaction of an article about the main results and lessons learnt during the PROBIOGAS project	Article "PROBIOGAS : les résultats d'un cas d'étude en région wallonne" for the newspaper plein champ (to be published in august)

The Belgian Assessment report: English and French version and the final assessment report (English version) are available on our website (www.valbiom.be).

Impact of PROBIOGAS

Through PROBIOGAS project and the formation of the TGN new discussions about the development of the sector of biomethanation in Belgium have started again and communication between members has been more proactive.
One point shown by the project was the importance to get enough organic material to be processed in biogas plant: not only the substrates have to be available in large amount but also have a high the potential of methane yield in order to ensure the profitability of the plant. It was shown in the economic analyses that despite the amounts of manure and waste from food-industries reached 200 tons/day (which is one of the bigger sizes among the 6 cases studies), the methane yield was the worse one: 50 m³ of biogas per ton of treated biomass. In the Belgian case calculations showed clearly that the profitability of the plant was not reached because of the lack of methane production. With this example, regional authorities became more aware of the importance using wastes from food-industries to increase the quantity of biogas produced. Previously, authorities were reluctant to use wastes from industries with agricultural manure in biogas plant and now, they have started to think about a positive list of by-products from industries which could be used for biogas production.

Another great interest of the project was the monetization of externalities. In the Belgian case, even when integrating externalities, the project, as it was studied, is not profitable.
The assessment of externalities like green house gases reduction, improvement of fertilizing value, reduction of N eutrophication of ground water, reduction of obnoxious smells… has been estimated to a value of 400 000 €/year. This is clear that the positive and negative effects of the biomethanation that are not actually taken into account by the market have a significant value for the society as a whole. Partly due to the project, the authorities are now aware about the extern effects of biogas production and utilization in terms of a source of renewable energy as well as an interesting economic and environmental alternative for wastes treatment. Nevertheless, it is not considered at this time to integrate the benefits of externalities in Belgium.
It should also added that thanks to the Green certificates system implemented in Belgium the price already paid for electricity and heat coming from renewable energy is high compare to other European countries.

The collaboration during the project with the group of Danish experts and the 5 other European countries lead to have close contact. This was important to know how the biogas chain is developing itself in other countries, to get information about the problems encountered and the solutions implemented in other countries. During the project a list of non technological barriers was elaborated in each participating country. Some recommendations or ways to remove those barriers were also studied by comparing the different situations. Some ideas could be implemented in Belgium but further information has to be collected and involvement and interest of various actors of biogas sector must not to slacken off.

Future: plans for further dissemination

In the following weeks, the Belgian partner is planning some actions:

- To write an article about biogas situation and new development in the sector in Wallonia. The Article will be published in the French edition of the “Bioenergie International” magazine (Edition of August 2007).
- To write a short report about PROBIOGAS results with the main conclusions and recommendations that should be emphasized in order to raise the non technical barriers that have been identified. This report will be addressed to the Walloon Ministry in charge of Agriculture & Environment and to the Walloon Ministry in charge of Energy.

- To meet and keep close contact with the 2 representatives of the agricultural biogas projects that were used fir the Belgian case study (project of Sprimont and project of Bilstain). It will be a matter of to see how PROBIOGAS results could help them to materialize their respective biogas plant project.

- To disseminate important results and lessons learnt during the project to a broad network of institutions or organizations involved in other European projects. By taking part in other R&D or Dissemination projects related to biogas production and utilization, CRA-W and ValBiom can share experience and knowledge with other European partners. Good communication about the follow-up of the project can be achieved by collaborating in new European projects. Networking is also a good mean to keep informed TGN members of biogas situation in other countries and help them to create international relations. (CRA-W is taking part in AGROBIOGAS project- 6th framework, ValBiom will be partner in BIOGAS REGIONS – ALTENER/IEE program)

The selected case study in Greece: Sparta in Laconia, Peloponnese region

By Christos Zafiris

Sparta is the capital city in the prefecture of Laconia, in Peloponnesus region with 19.102 inhabitants. It is situated in the north west of the prefecture, to the east of the mountain Taigetos at an altitude of 210m. The climate is Mediterranean and the average yearly temperature 17.4 degrees Celsius while average yearly rainfall, even present during summertime, is 817mm. Because of the particularity of the climate and the fertile territory, the economy is mostly self -supported. The region's farming and cattle rearing products are gathered and processed in the city's own industrial units.

Figure 7.12. Map of Greece and of province of Peloponnese /Sparta. The case study area is marked by the red circle

The risk of water pollution of both ground and surface waters is quite high in the area, because there are lots of agricultural activities and relatives industries. The Prefecture of Laconia has edited a document entitled "The water use for irrigation in Evrotas river", which defines the disposal limits of the treated waste water in the river of Evrotas that surrounds the city of Sparta.

The most significant biomass potential in the region comes from agricultural/forest residues as well as from agro–food industries and piggeries.

Table 7.23. Theoretically available biomass and bioenergy potential in Peloponnese

Biomass recourses	Biomass potential (dm/year)	Total annual energy potential (GWh/year)
Crops on arable land		
Wheat soft	5,660	28
Wheat hard	4,076	20
Barley	3,513	17
Oats	6,087	29
Maize	106,910	548
Total	126,246	643
Forest residues	18,500	77
Olives trees		
Alpechin-katsigaros	43,793	208
Husks	58,981	297
Pruning	128,874	613
Leaves – branches	17,592	93
Total	249,240	1,211
Vineyards		
Vineyard pruning	97,397	513
Vineyard residues	8,809	48
Total	106,206	561
Tree crops	*35,329*	*162*
Total	535,521	2,654

Table 7.24. Crop areas and fallow land, by categories (Year 2001)

	Greece, total (ha)	Peloponnese (ha)	Laconia (ha)
Total agricultural area	3,851,863	658,697	98,564
Total crops, incl. Fallow land	3,898,608	673,931	100,519
Crops on arable land	2,213,188	189,701	7,815
Garden area	118,719	25,344	2,015
Tree crops	972,633	287,672	72,342
Olive trees	767,144	230,944	60,372
Vines (grapes and raisins)	134,310	47,882	0,908
Fallow land	434,739	123,332	17,438

Description of the chosen site

Sparta is rather known for olive oil (60,372 ha) and fruits –mainly orange (72,342 ha) production activities as well for goat milk products.

Sparta is also very attractive for tourism and that means a high sensitivity on environmental protection and a high care for the public health.

Cattle raising (in its intensive dimension) is not a very promising agricultural activity compared to the advanced livestock systems found in northern Greece (Thessalonica, Pella, etc.). Also the increased meat and milk imports restrict the development of cattle breeding in Laconia.

On the other hand, pork meat production represents an increasing trend, despite the decrease in heads. This is due to advance animal raising practices and hence increases in productivity of the industrial pig farms.

Large quantities of untreated liquid manure from livestock, mainly from sheep and goats, are spread out on the surrounding grazing lands. In large-scale units, mostly equipped with a sewage plant, the slurry is disposed of as a good fertiliser for certain crops (orchards, vineyards, etc.). However, sufficient quantities of manure, mainly from pigs and chickens, remain unexploited while they could have been utilised for energy production.

Within the livestock sector, pig farms are considered a promising livestock activity.

Except for animal manure, a wide range of biomass resources in Laconia originates from the food processing industry wastes. The olive oil mill wastes, the distillery slots and the milk factory wastewater are produced in huge amounts and various qualitative characteristics. Their treatment is subjected to the Greek legislation. However, many problems have been created from the disposal of the untreated liquid manure and wastewater in the countryside (especially to river Evrotas), due to lack of any management fees or penalties.

In a short distance (10km) from the city of Sparta is situated the "Tsikakis – Giannopoulos" enterprise consisting of a 700 sows pig farm, a slaughterhouse and a pork meat factory where the Centralised Biogas Plant is proposed to be built.

The pig production of the farm is about 14,200 fattening pigs per year. According to the breading system used the daily animal population of the farm consists of about 650 sows, 1,090 suckling piglets, 1,640 weaners, 1,910 growers and 1,910 fatteners. Animal wastes (slurries) are treated to a private aerobic treatment plant next to pig farm. It is well known that the final quantity and the quality of pig farm effluent is related to several parameters such as nutrition, water intake, physiological stage of the sows, housing system, water used for cleaning and sanitation, etc. The wastewater from "Tsikakis – Giannopoulos" pig farm is collected in a tank followed by mechanical screening for solids separation. The amount of wastewater produced (in average) is about 100m^3 per day. The wastewater from the slaughterhouse and the meat factory are also treated to the same plant after their flow through a Dissolved Air Floatation system (DAF). The sludge collected by DAF system is about 1.5 m^3 per day.

Because of the lack of any other slaughterhouse in the greater area of Sparta, the "Tsikakis – Yannopoulos" slaughterhouse is also used for the slaughtering of cows, sheep, pigs from other farms, etc. That makes difficult the estimation of the quantities as well the quality of the effluent and the comparison with other bibliographic references. The average of wastewater produced by slaughterhouse and meat factory activities is about 100m^3 per day.

Bones, fat, other byproducts or no consumable parts of the fatlings are chopped, heated by steam and finally are centrifuged for oil and grease extraction. The management of the residue (given in the past as feed) is now a serious problem. It is estimated that 400 Kg of oil and grease and 400 Kg of "bone-meat" residues are produced daily. The produced oil and grease, is used - after melting- in a spray form to increase the energy value of dried olive husk which is the main combustible source to produce steam for several uses in the slaughterhouse, the meat factory and the treatment-sanitation of their solid wastes.

Proposed feedstock to the centralised biogas plant

The biomass resources actually available in the proposed biogas plant have been categorised and are presented in Table 7.25 below:

- Animal wastes (pig slurries, stomach contents, fat and bones)
- Wastes from cheese dairies (liquid wastes, water for cleaning and freezing)
- Wastes from orange processing (citrus fruit residues)
- Wastes from oil mill primary and secondary processing (katsigaros, olive husks, dry olive husk)

Table 7.25. Biomass resources actually available in the region of Laconia-Peloponese.

	Biomass categories	Feedstock types
1.	Animal wastes	Pig slurry, stomach content, fat and bones
2.	Waste and wastewater from agriculture related industries	
	A. Waste from oil mill primary and secondary processing	Katsigaros, olive husks, dry olive husk wood
	B. Waste from cheese dairies	Liquid wastes, water for cleaning and freezing
	C. Waste from orange processing	Citrus fruit residues

Why this case-study

The owner of the selected enterprise is a successful businessman with innovative ideas and efficient business plan. Tsikakis farm is one of the biggest farms in Greece. He is personally convinced and determined to proceed with biogas exploitation in his farm when conditions are favorable.

The site chosen is very suitable because it has good road access and is only 4 km away from the national road, allowing thus an easy access of the other surrounding farms and industries to the proposed biogas plant.

Furthermore, the integrated farm structure with pig production and slaughterhouse is ideal for setting up biogas plants because of:

- large amounts of on-site available biomass and
- high energy consumption in the particular plants.

Such a plant can be optimised through input from other waste products, mainly agricultural waste.

This “farm-type” biogas plant can benefit from the positive experience from the large Danish biogas plants and, at the same time, achieve optimised operation at a smaller scale through their energy integration with the slaughterhouse.

The possibilities of treating other types of organic wastes like cheese and orange residues and waste products from olive oil industry (katsigaros and husk) - provided technical problems are resolved - offer:

- environmental advantages,
- enlargement of the gas production and
- potential additional incomes (gate fee)

The calculations on the Sparta farm shows that a biogas plant digesting all the manure and additional organic wastes (cheese, orange and olive mill effluents) can supply 100% of the electricity and heat demand to the farm/slaughter-house and export approx. 1.5 GWh electricity/year to the grid.

Additionally, there are huge surpluses of heat that can be transformed to heating and cooling for in-house uses.

The manure and the slaughterhouse waste will be 60-90% of the biomass input (depending on time of the year) for the biogas plants considered.
A number of alternatives and a few additional technical solutions, as regards the type and the quantity of the chosen equipment and other implementation items, have to be taken into account when designing for each specific case.

Location of the proposed co-digestion plant

- **Area:** Sparta, Peloponnesus, South Greece
- **Name of beneficiary**: TSIKAKIS-GIANNOPOULOS S.A
- **Address**: Levki Anogion 23100, Sparti
- **Phone**: +30 27310 44679/44779
- **Fax**: +30 27310 44269
- **e-mail**: tsikakis@tgae.com
- **Exact location**: 22.44E 37.00N
- **Size of farm**: 10 ha (2 ha covering all activities of the unit and 8 ha cultivated with olive and orange trees)

Sparta is the capital city in the prefecture of Laconia, in Peloponnese region (Figure 1), with 19,102 inhabitants. It is situated in the North-West of the prefecture, to the east of the mountain Taigetos at an altitude of 210 m. The modern city in the fertile area of the Valley of Evrotas River, was founded in the same spot as ancient Sparta by enactment of the first king Othon in 1834.

The climate is Mediterranean and the average yearly temperature 17.4^{o}C, while average yearly rainfall, even present during summertime, is 817 mm.

Sparta is rather known for olive oil and fruits (orange) production activities as well as for goat milk products. It is also very attractive for tourism which involves high sensitivity on environmental protection and high care for the public health.

Apart from ‘Tsikakis – Giannopoulos’ pig farm, a number of olive oil mills, orange processing factories and cheese-dairies exist in the nearby area (in a 25 km radius). According to information collected, the problem of waste management is of a great importance.

Technical outline

In the Sparta case-study the plant is assumed to receive approx. 16,700 tonnes of pig manure, and approx. 17,200 tonnes of organic waste. The organic wastes come from food processing industries situated nearby. The biogas is used for electricity and heat production. Electricity will be sold to the grid, but no utilisation for heat production has been found.

From this biomass 1 mill. m^3 CH_4 production is calculated. In the CHP plant this energy is converted into electricity and heat. The electricity production which may amount to 3.7 mill. kWh is sold to the grid, heat production, which may amount to 5.2 mill. kWh cannot be utilised apart from what is needed for process heating.

The centralised anaerobic digestion plant will have a treatment capacity of approx. 34,000 tonnes on a yearly basis or 93 tonnes per day. The plant is operated at thermophillic temperatures, which means 52-55^{o}C. and 15 days retention time. The plant is equipped with 70^{o}C pre-sanitation step, heat exchanging, biogas cleaning facilities, odour control system, storage facility for biogas and CHP plant for heat and power production.

The manure and organic waste is unloaded in the unloading hall and entered into the pre-storage tank. From there it is pumped to the mixing tank in which the biomass is properly stirred and the optimal composition is ensured. From the mixing tank the biomass is pumped to one of the sanitation tanks. It is pumped through the heat exchangers, in order to recover heat from hot, sanitised or digested manure that is simultaneously pumped out of the other sanitation tank or the digesters. By this it is heated to 70^{o}C and kept inside the sanitation tank for one hour. After that it is pumped through the heat exchangers once again, and into the digester (1400 m^3), where the biogas production takes place. After 15 days in the digester, the now digested manure for the last time is pumped trough the heat exchangers and into the manure storage tank. From the storage tank, the manure is loaded on to trucks and returned to storage tanks at the farms.

The biogas is cleaned in a biogas cleaning tank in a biological process and sent to the CHP plant for conversion into heat and power. The electricity production capacity of the CHP plant is estimated to approx. 400 kW electricity

Odor emissions from the plant are controlled by sucking away air from the unloading hall, the pre-storage and mixing tanks, and cleaning it in a biological odor filter.

Investments

All investments, sales and operating costs are calculated in 2005 prices.

Investments in the biogas plant cover all investments needed for construction and operation of the biogas plant itself. Thus, site for construction, excavation and for example conjunction costs and needed manure pick up installations at the farms, are included.

As mentioned before, transportation of manure is made by means of trucks. Investment costs do not include truck investments, as it is assumed that haulage is rented from external operators. Farmers are assumed to take care of storage of manure. Storage of digested organic waste is assumed to be a matter of the CAD plant. Apart from this, only limited storage capacity is included at the plant to meet the needs of the day-to-day operation.

The biogas is converted in a combined heat and power producing facility. The CHP facility is dimensioned from the expected biogas production.

Investments are assessed as follows

Biogas plant	2,678,000 EUR
CHP facility	286,000 EUR

Economic results

In the study no market for heat production was found. Based on Danish experience, this is a serious disadvantage, as the dependence on electricity production and the price of electricity sold increases dramatically. However, significant treatment fees from receipt of organic waste can be obtained. In fact the amount from treatment fees exceed the value of electricity sales.

The electricity price used for the economic assessment was 0.069 EUR/ kWh, which is a relatively low price. Currently, it is raised up to 0.073 EUR/ kWh.

As mentioned before, haulage is assumed rented from external operators. In that way optimal transportation costs can be obtained. Again costs are assessed using models based on Danish experience. The capacity of the trucks in use is assumed to be 20 tonnes load. At average distance of 15 km, transport costs regarding transport of liquid manure to the plants are estimated to 2.4 EUR/ tonne, and 3.7 EUR/ tonne for solid manure. In the calculations an interest rate of 5.5% per year is used. Economic performance is showed in Table 7.26.

Table 7.26. Economic performance of the plant

	1000 eur per year
Transportation costs	-45
Digested waste storage costs	-0,1
Net result of the biogas plant	129
Profit	84
Profit if biogas production was increased by 10 %	64
Profit if biogas production was decreased by 10 %	104

It appears that the biogas plant itself is estimated to be economic. When transport and waste storage costs are taken into account it appears that the system as a whole is economic.

Socio-economic/cost-benefit analysis

The socio-economic analysis looks at the biogas-scheme from the point of view of the society at large. Therefore all consequences of the scheme in any sector of society should in theory be taken into account, - including externalities.

Socio-economic fuel prices are based on IEA (International Energy Agency) and DEA (Danish Energy Authority) forecasts of future fuel prices.

Electricity purchase is assumed at the socio-economic price that includes costs for transmission and distribution. Sale of electricity, however, is assumed to get the spot market price for electricity. Diesel and gasoline prices `an consumer` have been assumed. It is assumed that heat production from the plant cannot be marketed.

A quantification and monetisation for reduction in nitrogen leakage to ground water have been based on Danish general assumptions. N leakage reduction is 25% of saved chemical N fertiliser, monetised by the value of 3.36 EUR/kg N. It should be emphasised that considerable uncertainty is associated with these assumptions and these may not apply fully in the Dutch case. Specific data for the Greek case have not been available for the present analysis.

Reduction in green house gas emissions resulting from the operation of the CAD plant, occur from a variety of sources. Most important is the GHG reduction from the electricity production, as electricity based on fossil fuels are thereby substituted.

Other reductions occur from the digestion of organic matter in the plant, which leads to less CH_4 emissions during storage and reduced N_2O emissions from soil after manure spreading. In addition, CO_2 emissions are reduced when chemical fertiliser is substituted. However, also increases in GHG from the operation of the plant were estimated. Transport of manure to the plant increases the diesel consumption, and thus GHG emissions, and finally a small proportion of the fuelled CH_4 leaves the CHP- plant unburned.

The relevant gases, CO_2, CH_4 and N_2O, differ with respect to their global warming potential (GWP); for a time horizon of 100 years, the Global Warming Potential (GWP) of CH_4 is 21 times higher than that of CO_2 (on a weight basis)[2], whereas the GWP of N_2O is 310 times higher than that of CO_2 (Houghton et al., 2001). In the analysis, CH_4 and N_2O emissions are expressed as CO_2 equivalents.

Estimated GHG reductions are shown in Table 7.27.

Table 7.27. Estimated green house gas emission reduction

Concequence on annual GHG emission:

		Alternative - Reference		%-split	Equivalent CO2 %-split
CO2:					
	Gas-sales	0	ton CO2	0	0
	EL-sales	-2320	ton CO2	85	41
	Heat-sales	0	ton CO2	0	0
	NPK substitution	-453	ton CO2eq	17	8
	Transport fuel	44	ton CO2	-2	-1
CO2-equivalent.:		-2729	ton CO2	100	**48**
CH4:		Alternative - Reference		%-split	Equivalent CO2 %-split
	Animal manure	-40	ton CH4	34	15
	Organic waste	-88	ton CH4	76	32.75
	CHP-plant unburnt	12	ton CH4	-10	-4.30
Total CH4		-116	ton CH4	100	
CO2-equivalent.:		-2435	ton CO2 equivalent		**43**
N2O:		Alternative - Reference		%-split	Equivalent CO2 %-split
Total N2O / Manure, Waste		-1499	kg N2O	100	
CO2-equivalent.:		-465	ton CO2 equivalent		**8**
GHG in total					
Reduction in CO2-equivalent:		**-5630**	**ton CO2 equivalent**		**100**
Specific CO2-reduction:		**-0.166**	**ton CO2 equivalent / ton biomass**		

In the socio-economic analysis CO_2eq. emission reductions achieved are monetised via an assumed market value of the CO_2 emission allowances (20 EUR/tonne CO_2). Monetised costs and benefits are included in the socio-economic profitability analysis. The results from this analysis are presented in Table 7.28.

Table 7.28 shows socio-economic deficits of 0.3 mil EUR, when only the value of the very energy production is included. But when agricultural and environmental externalities are taken into account the results gradually improve, and the CAD plant appears to exceed the point of socio-economical profitability, when all externalities are taken into account.

Table 7.28. socio-economic costs and benefits for the CAD plant

Socio-economic results **Biogas plant:**
Annual costs and benefits **Sparta, Laconia Peloponese, Greece. Base Case**

Costs (levellised annuity)	Result 0	Result 1	Result 2	Result 3
		mio.EUR/year		
Invesments:				
Biogas-plant	0.249	0.249	0.249	0.249
Transport materiel	0.000	0.000	0.000	0.000
CHP-plant	0.025	0.025	0.025	0.025
Operation and maintenance:				
Biogas production / biogas plant	0.180	0.180	0.180	0.180
Transport materiel	0.006	0.006	0.006	0.006
Sum:	**0.460**	**0.460**	**0.460**	**0.460**

Benefits (levellised annuity)	Result 0	Result 1	Result 2	Result 3
		mio.EUR/year		
Energy production:				
Biogas sale	0.000	0.000	0.000	0.000
Electricity sale	0.126	0.126	0.126	0.126
Heat sale	0.000	0.000	0.000	0.000
Agriculture:				
Storage and handling of liquid manure		0.000	0.000	0.000
Value of improved manurial value (NPK)		0.076	0.076	0.076
Distribution of liquid manure		-0.036	-0.036	-0.036
Transport savings at farms		0.004	0.004	0.004
Veterinary aspects				n.a.
Industry:				
Savings related to organic waste treatment		0.278	0.278	0.278
Environment:				
Value of GHG reduction (CO_2, CH_4, N_2O-reduction)			0.114	0.114
Value of reduced N-eutrophication of ground water:			0.037	0.037
Value of reduced obnoxious smells				0.008
Sum:	**0.126**	**0.448**	**0.598**	**0.606**

	Result 0	Result 1	Result 2	Result 3
		mio.EUR/year		
Difference as annuity: Benefits - costs	**-0.334**	**-0.012**	**0.139**	**0.147**

Cost efficiency of the CAD plant regarding GHG reduction cost has also been estimated. The results are showed in Table 7.29.

Table 7.29. Green house gas reduction costs

Level of analysis	Reduction costs eur/tonne CO_2
Result 0	59 eur/tonne CO_2
Result 1	2 eur/tonne CO_2
Result 2	-4 eur/tonne CO_2
Result 3	-6 eur/tonne CO_2

Collaboration with TGN

The creation of the national Target Group Network (TGN) established in this project will assure constant and efficient linking between different policies – on energy, environment, etc – and marketing activities on biogas deployment. It is worth mentioning that interest of the members of the group was noted for international experience exchange and cooperation, transfer of knowledge and dissemination.

Through the creation of this national group, close contacts with involved parties have been established. These contacts resulted in the identification of the various categories of the “key players” and the determination of the planning network. The main contacts have been made with SMEs, technology suppliers, specialised contractors, equipment manufactures, financing providers, policy makers (Ministries, Local Authorities) etc. The market partners were approached and formed links with the policy makers, local authorities and other key players, for the creation of local formations/clusters and development of networking schemes. The aim of such schemes would be to determine synergies, dependencies and interactions between the involved key players for each stage of a biogas plant life cycle and find out which productive systems can be derived.

The involvement of the TNG members is expected to continue being active during and after the completion of this project. The committee was/will be regularly supplied with information about the latest developments on the biogas production in Europe and Greece and is expected to give feedback when required.

During the project meetings were scheduled at crucial project phases (Photo 1).

Figure 7.13. Meeting of TGN at CRES

Other informal contacts were regularly made at different forums and events, as well as by e-mail and phone facilities. Through these actions awareness was raised among general public for the possibilities of the biogas applications in Greece.

From the technical part of view, the most crucial achievement from these activities was that a clear picture on the biogas state-of-the-art and possibilities for its deployment in Greece was drawn.

Dissemination activities

Through the creation of the national Target Group Network, close contacts with involved parties have been established. These contacts resulted in the identification of the various categories of the “key players” and the determination of the planning network.
The main contacts have been made with local farmers, SMEs, technology suppliers, specialised contractors, equipment manufactures, financing providers, policy makers (Ministries, Local Authorities) etc.
The training action held in the frame of this project was announced and the results were presented in:

- 1 interview in the Regional TV (in the headlines)
- 1 daily newspaper of a wide-range
- 2 daily local newspapers
- 4 monthly scientific magazines

- The web-site of CRES
- Two international conferences

  - *'From waste disposal to resource and energy recovery'* held in Athens, February 3-4th 2006, organised by the Hellenic Solid Waste Management Association (HSWMA)

  - *'Alternative Biofuels'* held in Athens, January 27 – 28th 2005, organised by the Federation of Chemical Engineers.

- The leaflets of the project (in Greek).
- Six training events in the regional level in Greece

The project and its targets are presented in six training sessions related to energy exploitations of biogas applications and waste management, in Athens 09.03.2006, Thessalonica 06.06.2006, Patras 15.06.2006, Crete 04.07.2006, Kozani 08.03.2007, Thessalonica 18.05.2007. The training sessions were organised by the peripheral units of the National Centre for Public Administration and Local Government, which aim at training the personnel of public services so as they became competent and properly educated in matters that affect local sustainable development.
A number of separate meetings with the main SMEs and end-users were also held to promote biogas applications in Greece, through national or European projects and also to initiate a public dialogue with the local community.

Ημερίδα για την αξιοποίηση του βιοαερίου στην Σπάρτη

Ημερίδα εργασίας με τίτλο «Οικονομικά και περιβαλλοντικά οφέλη από την ενεργειακή αξιοποίηση του βιοαερίου» οργανώνει στην πόλη μας το Κέντρο Ανανεώσιμων Πηγών Ενέργειας.

Η ημερίδα θα γίνει στο ξενοδοχείο «Σπάρτα Ίνν» στις 25 Μαΐου, Τετάρτη και ώρα 9 το πρωί.

Τη συζήτηση θα συντονίσουν ο κ. Γ. Μπουραζάνης από τη Διεύθυνση Γεωργίας Λακωνίας και ο κ. Χρήστος Ζαφείρης από το ΚΑΠΕ.

Η ημερίδα θα αρχίσει με χαιρετισμό του νομάρχη κ. Κ. Φούρκα.

Στη συνέχεια θα γίνουν οι εξής εισηγήσεις:

- Προοπτικές αξιοποίησης βιοαερίου, από τον κ. Χρ. Ζαφείρη.
- Η ιδέα της κεντρικής μονάδας αναερόβιας χώνευσης, από τον κ. Κουρτ Γκρέκενσεν (Δανία).
- Πλεονεκτήματα στο περιβάλλον και τη γεωργία, από την αναερόβια χώνευση αποβλήτων, από τον κ. Τόρκιλντ Μπίρκμος (Δανία).
- Επεξεργασία κτηνοτροφικών και αγροτοβιομηχανικών αποβλήτων για παραγωγή βιοαερίου στην περιοχή Σπάρτης, από τον κ. Αντώνη Ζαχαρόπουλο (Εταιρεία «Έδραση») και
- Ενεργειακή αξιοποίηση βιοαερίου, από τον κ. Γιάννη Μπούκη (Αλέκτωρ ΑΕ).

Τέλος, θα γίνει συζήτηση για την κεντρική μονάδα βιοαερίου στη Σπάρτη.

Περισσότερες πληροφορίες σχετικά με την ημερίδα δίνονται από τον κ. Χρ. Ζαφείρη στο τηλέφωνο 210-6603300 και από τον κ. Λάμπρο Τσικάκη στα τηλέφωνα 27310-44679 και 44779.

Figure 7.14. Article in the local newspaper 'The Lakonian News' announcing the workshop

Πολλά τα οφέλη από την παραγωγή βιοαερίου

Μια ενδιαφέρουσα ημερίδα με θέμα «Οικονομικά και περιβαλλοντικά οφέλη από την ενεργειακή αξιοποίηση του βιοαερίου», πραγματοποιήθηκε την Τετάρτη 25/5 στο ξενοδοχείο Σπάρτα Ινν.

Συνδιοργανωτές της εκδήλωσης, ήταν το Κέντρο Ανανεώσιμων Πηγών Ενέργειας και η Διεύθυνση Γεωργίας της ΝΑ Λακωνίας.

Κεντρικό ρόλο στην εκδήλωση, είχε ο γνωστός και πάντα δραστήριος επιχειρηματίας του τόπου μας, κ. Λάμπρος Τσικάκης.

Ο κ. Τσικάκης ήταν επίσης ο συνδετικός κρίκος, ανάμεσα στο ΚΑΠΕ και στη νομαρχία. Είναι ακόμη, προνομιακός συνομιλητής του Κέντρου, καθώς η κτηνοτροφική μονάδα που διαθέτει, μπορεί να δώσει τη βασική πρώτη ύλη για την παραγωγή βιοαερίου. Δεν είναι τυχαίο άλλωστε, ότι μία από τις πέντε περιοχές που επιλέχτηκαν απ' όλη την δα, οι κ. κ. Ζαχαρόπουλος της εταιρείας Έδραση και Γιάννης Μπούκης από την εταιρεία Ηλέκτωρ ΑΕ.

Βασικό μέλημα των ανθρώπων, που ενδιαφέρονται για την προσέλκυση μιας επένδυσης στον χώρο της παραγωγής βιοαερίου στη Λακωνία, μεταξύ αυτών και ο κ. Τσικάκης, είναι η δημιουργία προϋποθέσεων ανάπτυξης του τόπου με ταυτόχρονη προστασία του περιβάλλοντος.

Το βιοαέριο παράγεται κυρίως απ' ό,τι θέλει ο άνθρωπος να ξεφορτωθεί. Από τα σκουπίδια, τα λύματα, την κοπριά των ζώων. Παράγει θερμότητα, ηλεκτρισμό, ενώ μπορεί να χρησιμοποιηθεί στο δίκτυο φυσικού αερίου, ακόμη και για να κινήσει αυτοκίνητα.

Στην ΕΕ, η τεχνολογία του βιοαερίου είναι πια τεχνολογία αιχμής. Στην Ελλάδα, παρά τον εμπλουτισμό της σχετικής νομοθεσίας και το υψηλό δυναμικό που υπάρχει στην κτηνοτροφία, δεν υπάρχει καμία μονάδα διαχείρισης για παραγωγή βιοαερίου από κτηνοτροφικά απόβλητα και αγροτοβιομηχανικά λύματα.

Η χρήση του βιοαερίου έχει μικτά οφέλη. Στο επίπεδο της προστασίας του περιβάλλοντας, βοηθάει να επιλυθούν τα προβλήματα διαχείρισης αποβλήτων και απορριμμάτων, ακριβώς επειδή τα χρησιμοποιεί σαν πρώτη ύλη και επιτυγχάνει την παραγωγή ρεύματος και θερμότητας, χωρίς να εκλύονται κατά τη διαδικασία, αέρια του θερμοκηπίου. Δίνει τέλος, τη δυνατότητα να λειτουργήσουν μηχανές εσωτερικής καύσης πχ αυτοκίνητα, καυστήρες κλπ.

Σε οικονομικό επίπεδο βοηθάει στη μείωση της ενεργειακής εξάρτησης από τρίτες χώρες, την αντίστοιχη εξοικονόμηση συναλλάγματος και αποφέρει κέρδη στις επενδύτριες εταιρείες.

Στιγμιότυπο από την ημερίδα.

Figure 7.15. Article in the local newspaper 'The Lakonian News' announcing the results of the workshop

The impact of PROBIOGAS and achieved results

The impact of PROBIOGAS in the Greek case is:

- To asses and quantify a range of environmental and economic costs and benefits in the specific case-study. These will also serve as a basis for relevant assessments in other similar case-studies.
- To give a clear picture of the specific incentives and non-technical barriers for the development of biogas in Greece.
- To disseminate, transfer and implement European level knowledge, positive results and experience in a local/regional level.
- To provide a platform of documentation and to offer incentives for the decision makers and the biogas investors to initiate and develop biogas projects
- To create platforms for the development of new policy initiatives
- To motivate decision and policy makers to initiate necessary legal changes to remove non-technical barriers
- To enable the Target Group Networks to form the organisational structure necessary for initiating specific biogas projects.
- To further develop the European biogas market and the market for biogas based electricity and heat
- To accelerate the development of biogas systems all over Europe

The achieved results

- Assessment of environmental costs and benefits for the Greek case study – in cooperation with the Danish experts
- Database with key stakeholders in Greece
- National TGN of stakeholders well established
- National workshop with 50 participants
- National report for the state-of-the-art of biogas in Greece
- Dissemination workshops in different areas in Greece (Athens-Thessalonica-Creta-Patra)

Additional results involve:

- ***Web site***: which constitute one of the main channels for dissemination.
- ***Information material:*** production leaflet, transparencies, distribution in all the country
- ***Presentation*** of the project activities and deliverables at conferences, seminars and meetings
- ***Articles*** will be published in journals and in other relevant context.

Plans for further dissemination

- So far, a biogas target group network farmers' associations, agro-industries companies, industries/end-users, technology vendors, contractors, equipment manufacturers, local authorities has been formed, whose members are actively involved on the subject. It is worth to mention that interest of the members of the group was noted for international experience exchange and cooperation, transfer of knowledge and dissemination.

Through the creation of this national group, close contacts with involved parties will be kept, so that they are continuously informed on all recent developments on this subject.

- Having assessed and quantified the environmental, economic and socio- economic effects of implementing centralised co-digestion in the respective area, significant knowledge has been created and 'translated' into financial input for the biogas plants. This information is disseminated through the target network group and is expected to positively influence the traditionally strong resistance of local societies in Greece.
- Having determined existing barriers to the development of biogas plants, information on future policies and financial incentives on a European or national level will flow to the target group, so as to initiate future investments when possibilities are in favour.
- The project results will continue to be presented in relevant future events/workshops/training sessions.

The selected case study in France: Midi Pyrenees, West Aveyron area

By Christian Couturier

The French case study is located in the "Pays du Rouergue Occidental", the west part of the department of Aveyron, in région Midi-Pyrénées (south-west of France). A study has been lead in Midi-Pyrénées in order to assess the methane production from agriculture, and to propose solutions in order to decrease these emissions.

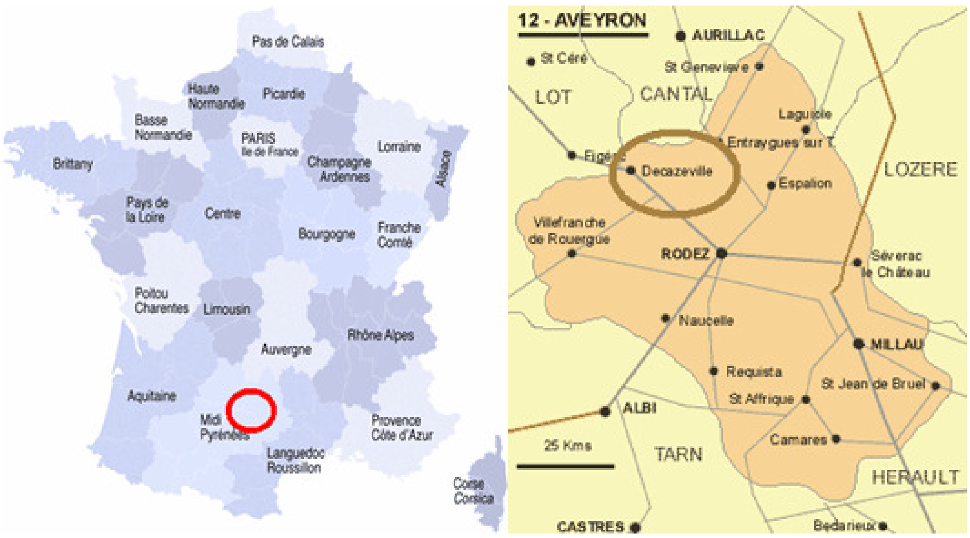


Figure 7.16. Map of France and of Aveyron region. The case study area is marked by the red circle

The manure production in West Aveyron is estimated at 1 million tonnes (160,000 tonnes of dry solids), of which 2/3 from cow breeding and 1/3 from swine. The Canton of Montbazens is the main producer, with 36,000 tonnes of dry solids. This is the main concentration of manure production of all Midi-Pyrénées.

Many food industries are established on the River Lot, or near the main cities in a 20-30 km radius area. Most of them are meat industries. The biogas project could be a solution for 6,000 to 9,000 tonnes of wastes and by-products.

Location of the plant

The centralised anaerobic digestion plant could be implemented in the neighborhood of Montbazens. The proposed name of this project is PRO-Biogas, i.e. "Pays du Rouergue Occidental – Biogas"

The CAD plant will process mainly swine and cow liquid manure, some quantities of cow solid manure, and several types of non-farm wastes from the surrounding area. The plant will be supplied by 20-30 farmers, within a radius of about 10 km on the Montbazens plate. The area is delimited by River Lot and River Aveyron valleys, and the hillsides are a difficulty for the transportation of the manure out of the area.

The heat produced by the Combined Heat and Power (CHP) plant should be used by a food-industry. The raw biogas will be carried by a biogas pipeline of about 13 km from the CAD plant to the food industry plant. The CHP will deliver electricity to the grid, and will generate steam for the industry process.

Other opportunities are studied: for example, the district heating of the 5,000 inhabitants neighbor city of Capdenac Gare, or the coal district heating of Decazeville city, both 15 km from the CAD plant.

Materials for digestion

The first targets of the CAD project are the swine breeding: 12,000 places of fattener pigs (about 35,000 pigs are produced each year). 33 farms, members of the local farmer's organisation, have been studied in order to evaluate the availability of manure for the CAD plant. Most of them breed both cows and swine. The total production of this sample is approx. 38,000 tonnes of manure, of which 70% swine slurry, 20% cow slurry, and 10 % cow solid manure.

A huge amount of solid manure is also available. Municipalities may be interested by treating urban sludge. All these substrates may be taken into account in the future. For the present calculation, the project is limited to the breeding producing mainly liquid manure, and to selected food industry waste, i.e. about 44,000 tonnes of materials.

In France, electricity from renewable sources is bought by the distribution companies, such EDF, at a tariff established by a governmental decree. Until now, the purchase tariff for such a CAD plant did not exceed 68 EUR/MWh. This tariff has just been modified in July 2006: for the West Aveyron CAD plant, the tariff should rise to 130-135 EUR/MWh.

The feasibility of the gas canalisation, due to its length, is one of the key-points of the project. The electricity purchase tariff grants an "efficiency bonus" of 0 to 30 EUR/MWh electricity according to the amount of co-generated heat really used. In the case of the West-Aveyron CAD plant, the bonus should be 14 EUR/MWh electricity, and the revenue from steam sales and efficiency bonus will be more than 200,000 EUR/year, compared to the estimated investment in the gas canalisation of 820,000 EUR.

The digested material will be used on both grassland and arable land as a fertiliser. Today, farmers use mineral nitrogen in addition to raw manure. Anaerobic digestion will bring a positive nitrogen balance, so farmers could save on purchasing mineral nitrogen and export the excess to arable crops. One key-point is the acceptance of waste spreading on farmlands. Farmers are very sensitive to the quality of digestate: control of incoming wastes, analysis of digestate, fertilising value etc.

West Aveyron area

The French case study is located in the “Pays du Rouergue Occidental”, the west part of the department of Aveyron, in region Midi-Pyrénées (south-west of France).
The manure production in West Aveyron is about 160.000 tons of dry solids, of which 2/3 from cow breeding and 1/3 from swine. Montbazens area is the main concentration of manure production in Midi-Pyrénées, with 36.000 tons of dry solids.
Food industries are established on the River Lot. Most of them are meat industries. The biogas project could be a solution for 6.000 to 9.000 tons of wastes and by-products.

Digestate

The digested material will be used on both grassland and arable land as a fertiliser.
Today, farmers use mineral nitrogen in addition to raw manure. Anaerobic digestion increases the nitrogen availability, and the farmer will be able to spare mineral nitrogen. Moreover, the nitrogen balance will be positive, the farmers may export nitrogen. Arable crops land would benefit from free nitrogen, and spare in the whole 90 €/ha.

Costs

The plant investment is calculated at 4,8 M€, including the CHP plants (0,6 M€) and the biogas canalization (0,8 M€). The feasibility of the gas canalization, due to its length, is one of the key-point of the project.

The sales exceed 1 M€/year (including power and steam sales and treatment fees for wastes), and the operating costs
0,3 M€ (mainly maintenance and staff).

A part of the digestate will be transported to crops area. The additional transportation and storage costs are 60 k€/year, and the annual saving in mineral fertilisers is 83 k€.
In the whole, the net annual income reaches 0,3 M€/year, and the Internal Return Rate is 11%.

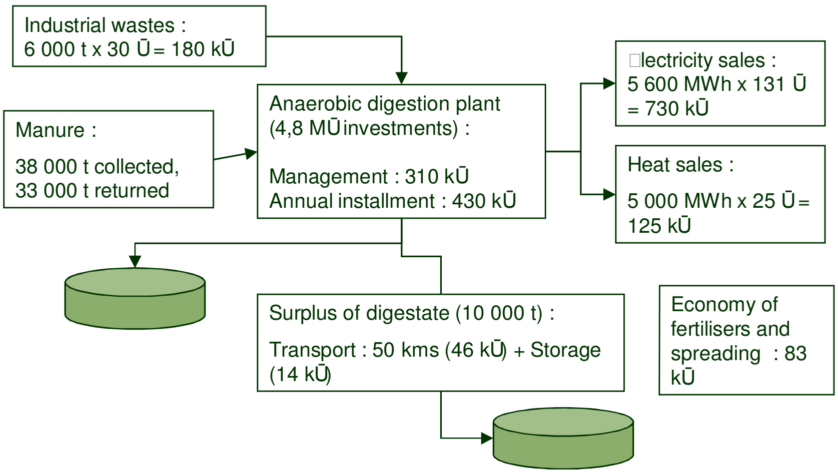


Figure 7.18. Main costs

Environmental results

The CAD project will save 40 tons of mineral N, 31 t of P_20_5 and 35 t of K_20, due to the better use of manure and the addition of wastes.
The GHG reduction reaches 8.400 tons of eq. CO_2. This is due mainly to the reduction of methane during storage (6.000 t eq. CO_2) and to the substitution of fossil fuels (2.400 t of CO_2).

The collaboration with the TGN

Local target groups and national target group

Due to the size of the country, the decision have been taken to create a local target group, at the regional level, and to consider the existing Club Biogas as a national target group, at the national level.

The task of the local target group includes collection and validation of the data for the project; the task of the national target group concerns the regulation field.

The National target group: the Club Biogas
The Club Biogas have created different work groups – power production, regulation, agriculture are actually the more active (see: http://www.biogaz.atee.fr)
Its annual meeting gather most of the French biogas community: waste treatment companies, energy companies, administration, engineering, farmers' organizations, and manufacturers…
The Club Biogas organizes training session and technical tours (Germany, Luxembourg, Belgium, France), for technicians and for members of the department of agriculture, energy and environment.
The PROBIOGAS programme have been presented during the Annual meeting of the CLUB BIOGAZ in December 2005, in presence of representatives from the Department of agriculture, Department of environment, Department of industry, ADEME, Gaz de France, Electricité de France, the network of French Regional Councils, manufacturers, biogas plants owners, investors, etc.
Participants expressed their interest for an extension of a « PROBIOGAS programme » to other regions, and for the link between energy, agriculture and environment underlined by the CAD concept.
During the first semester of 2006, intensive discussions have been lead with different organizations (farmers organizations, national authorities) in order to contribute to the public debate, since the Minister of Environment announced that the purchase tariff for electricity from biogas would be updated.
Finally the decree was signed in July 2006, and the feed-in tariff has been increased by 50 to 100 %.

The West Aveyron and the TIPER project
At the local level, the target group included food companies (A.D.R, CAPS SARL, FIPSO Industrie, Raynal et Roquelaure, Soulie Restauration SA), farmers organizations (Chambre d'agriculture de l'Aveyron, Midi-Porc), institutions (ADEME, ARPE), local authorities (Regional Council, Communauté de Communes de Decazeville-Aubin), agricultural school (Lycée de la Roque), technical centers (Centre Technique de la viande, C.T.C.P.A.), energy companies (Gaz de France), local energy agency (Quercy-Energy), administration (DSV), project developers (ADELIS).

The first meeting with the local target group occurred in Decazeville, on June 1st 2005.
The task of the second period, from June 2005 to December 2005, consisted in collecting the data and building a first draft of the project.

SOLAGRO carried out a survey of industrial organic waste, and another survey on manure potential. Dozens of companies, farmers and technicians from farmers' organizations, municipalities, were interviewed. The aim was to evaluate the potential for a biogas plant on a quantitative point of view (quantity of substrate, characteristics) and also a qualitative point of view (alternative treatment costs, acceptability for the exchange of manure to digestate).

The inquiry did not deal only with slurry production, but also with the use of digested slurry and the impact on fertilization, including chemicals; the risks with non-farm wastes linked to the quality labels for some farmers associations, and the fact that these labels may forbid the spreading of food-industry waste; the real benefits of CAD for farmers.

Food-industry is, in its whole, very interested by the concept of CAD plant, most of them have kindly collaborated on the programme.

The main difficulty remains a relative lack of representative of the administration at a local level.

Other meetings took place at the end of 2006, when the report established by the Danish expert group was available.

Another CAD project have also been studied by SOLAGRO during the PROGIOBAS programme (TIPER, in North Deux-Sèvres, region Poitou Charentes). The local target group included also bank organisation (Caisse des Dépôts), waste treatment companies, mayors and elected persons.

The first meetings occurred in the middle of 2006. During the first phases, the assessment of organic waste and manure has shown the potential for biogas production. In parallel, the assessment of heat consumption, mainly in food industry, indicated the possible localizations of a biogas plant. The localization proposed on behalf of the TIPER project was confirmed: the main conditions – waste and manure availability, heat consumers – were fulfilled.

Due to the new biogas tariff, farmers wonder which is the best way: CAD concept (the « Danish way ») or individual farm-scale plants (« the « German way »). About 10 basic feasibility studies have been lead in order to compare each individual case, and the CAD project. It appears that few farm scale plants were viable in the North Deux-Sèvres context. The preconditions are now well known: size, heat use, waste treatment fee. In most cases, the collective project seems more conclusive than the farm-scale plants.

During the last period, a study has been lead in order to evaluate the technical and economical feasibility of the TIPER project.

For the both projects, several meetings, with few attendees, have been organised specifically for farmers and for food companies.

Dissemination activities and initiatives

The CAD concept and the PROBIOGAS initiative have been actively promoted during the programme duration.

This is an important part of a wider strategy about biogas. The dissemination activities usually concern biogas technologies in the whole, and not only CAD concept.

The new economical context in France generates many requests from farmers. The economy of the ongoing projects is widely changed. There is a paradox with this new tariff. It will surely boost the biogas technologies in the middle term. But immediately, projects carriers are waiting to see the consequences. Indeed, this would affect the nature and amount of the substrates to digest, and the sizing of the projects.

Another collateral effect is the concurrency between individual and collective projects. There is today a wide niche for farm-scale plants. Many farmers think that a farm-scale biogas plant could offer a direct income. In a collective project, the role of the farmers may be limited to exchanging raw slurry to digested one, with little benefice for them. So they are wondering if their interest is to participate to a collective biogas plant, or to build their own individual project.

In Deux-Sèvres for example, but also in the other areas, many farm-scale projects have been studied in order to evaluate their feasibility. These studies reveal that farm-scale projects may be economically viable only if they reach some criteria: scale, heat use, by-products.

For these reasons, it is important to consider not only CAD concept, but also biogas technologies in the whole.

SOLAGRO have participated to some national meetings, where the question of CAD, or biogas, or bioenergy policy in the whole has been discussed: for example

- Conference on biomass in October 2005, following the European bioenergy conference in Paris, where most of the French actors in the field of bioenergy where present;
- Annual meeting of TRAME, one of the main farmers organizations in France involved in biogas technologies.
- 1st INTERNATIONAL BIOMASS CONGRESS in Valladolid (Spain) 18-20th October 2006; presentation: « Centralised anaerobic digestion: application to French rural areas »
- Seminar « Waste and Territory », ADEME, Paris, 20th June 2007; presentation: « Anaerobic digestion at a territory scale »

With AILE, another agricultural organization situated in Brittany, we have written a leaflet for the Department of Energy, explaining the needs for a new purchase tariff for electricity. The calculation for CAD projects was in a great extent, based on the Danish experience. The main farmers' union has supported these proposals. The new tariff matches these wishes.

Figure 7.19. Technical tour in Germany, July 2006. Farmers and agricultural organizations (technical institutes, cooperatives, schools).

The partnership between AILE, TRAME and SOLAGRO, with the support of ADEME, will lead to new tools and will be extended: calculation tools for farm plants, study tours in Europe, training…

Links are being set up with technical institutes (*Institut technique du Porc, Institut de l'Elevage, Institut technique de l'Aviculture*). This is an important change, because these institutes showed until now little interest to biogas. The programme METHASIM gathers most of agricultural institutes. Its aim is the creation of a calculation tool. The first task is the inventory and comparison of existing tools in Europe.

AMORCE is another organization involved in biogas development. AMORCE represents municipalities and companies concerned mainly by district heating, waste and energy. It has defended the idea of the efficiency bonus.

In parallel to these activities, SOLAGRO organised seminars and technical tours, for different publics:

- Biogas plants, for farmers and farmers organizations, in Germany (1-2 March 2006, 3-5 th July 2006)
- Renewable energy strategy for municipalities, in partnership with IFORE (French training institute for government officials): Austria (Güssing: 26-28th Sept. 2006), with a visit of a collective biogas plant; Germany (farm scale biogas plant near Freiburg: 5-7th July and 11-12th July 2006)
- Training session: biogas for agriculture (farm-scale and centralised projects): Toulouse, 22-23rd April 2007; Lyon, 14-16th June 2007 (in collaboration with ITEBE: Institut Technique Européen des Bio Energies)

Figure 7.20. Technical tour in Germany (Freiburg), July 2005, in partnership with IFORE (public administration in charge of the training of all public officers about environmental issues).

Another way of dissemination is the technical press:

- Article « *Méthanisation territoriale: initiatives hexagonales* », in BIOENERGIES n°1, June 2007
- Article in ENVIRONNEMENT MAGAZINE (to be published, Aug. 2007)
- Article in LA GAZETTE DES COMMUNES (Feb. 2006)
- Solagro website: PROBIOGAS page: Activity Report 2007

Papers have also been published in the local press.

The impact of PROBIOGAS

The main change for biogas policy was the publication in July 2006 of the new **electricity purchase tariffs**, by the government.

This new tariff creates a favourable environment for the development of biogas technologies, for all applications: farm-scale plants, centralised plants, municipal and industrial solid and liquid wastes. The electricity price may reach 140 €/MWh for power plants under 150 kW el. if the heat is correctly used. The minimal price for biogas from a biogas plant is 95 €/MWh (power over 2 MW el, no heat use).

Unlike Germany, there is no incentive for energy crops. From an economical point of view, the price for electricity does not allow, usually, the use of energy crops.

Non-technical barriers are being studied:

- Creation of a work group at **AFNOR** for the normalization of solid digestate (2nd semester 2006)
- Creation of a new category **ICPE** (Intallations Classées pour la Protection de l'Environnement) « anaerobic digestion plant » in the environment regulation (project)

- Constitution of a work group by **AFSSET** (Agence Française de la Sécurité Sanitaire et Environnementale) dedicated to biogas injection to the gas grid (Feb. 2007)
- Constitution of a work group on behalf of the CLUB BIOGAZ, for the publication of a guideline about specific biogas canalization.

What now?

The CAD concept is now well known in France and the climate is favourable. Several projects are setting up: the GEOTEXIA project (Brittany) has been launched in 2001 and must face to many difficulties. Its aim is to export nitrogen from vulnerable nitrogen areas, by using biogas for the transformation of manure and waste into solid fertilisers.
A project lead by FERTI-NRJ in Picardie will treat only wastes from food industry; this project looks like a CAD plant, but without manure from farms. Other similar projects are under development; most of them are an extension of a composting facility.
In Lorraine, and in Aquitaine, two CAD projects are being studied: the plants should treat mainly solid manure from farms, and a little quantity of wastes.
The initiatives for such projects come both from farmers associations, and from developers. The developers are waste or power companies (some are active in both two fields): SITA (SUEZ), VEOLIA, AREVA, ADELIS, VALOREM, OXARA, and EPURON… Most of them are new players in biogas technologies.
In order to understand to role of each, a meeting will be organised on the cover of the CUMA movement. The CUMA movement (federation of groups for the collective use of agricultural machinery) is one of the most important farmers organizations. The meeting will occur during the SAFIR (**www.safir.cuma.fr**) in August 2007; the farmers involved in the main CAD projects will exchange points of view about the partnerships between farmers and developers, engineering, bankers, and other possible companies and institutions possibly involved in such projects. This meeting will be opened to French-speakers farmers, like the Belgium partners involved in the PROGIOGAS programme.

The funding of CAD plants is a major issue. The public financial institution « Caisse des Dépôts et Consignations » (CDC) have created a Carbon Fund in order to help projects of GHG mitigation. The CDC plays an important role in France and in Europe (Powernext Carbon, European Carbon Fund…), and is a partner of the two more advanced projects (Ferti NRJ and GEOTEXIA), and probably TIPER.

The selected case study in the Netherlands: Noord Brabant, region De Kempen, community of Bladel

By Bert van Asselt

As Dutch case for the European PROBIOGAS project SenterNovem choose an initiative in the south part of the Netherlands, region De Kempen, in the community of Bladel (south-west of Eindhoven). This region is characterised as an intensive agricultural area. In the table 7.30 below same figures of manure production, availability of bio-mass and numbers of animals (lifestock) are presented. The production of bio-energy for this area is estimated as 2,4 million GJ.

Figure 7.21 Map of the Netherlands and Noord Brabant. The case study area is marked by the red circle

Table 7.30. Characteristics biomass production Bladel area (year 2002)

Biomass	Type	Production/a	Remarks
Manure	Cattle and pork	2.5 million tonnes/a	Cattle 12,000 animals and Pork 225,000 animals
	Poultry	0.11 million tonnes/a	500,000 animals
Crops		4,650 ha/a	
Wood		0.35 million tonnes/a	
Waste	Organic community	0.15 million tonnes/a	

The communities around Eindhoven started a project to define the possibilities of sustainable energy in this region. This means that both the authorities (local and provincial) and the farmers can stimulate the initiative for large scale digestion of manure.

General considerations

At the start of the PROBIOGAS project co-digestion of manure in The Netherlands was difficult to realise. In this paper a summary of events with respect to the PROBIOGAS project concerning the development of co-digestion in the period 2005-2007 is presented.
Until 2005 digestion of manure in The Netherlands was carried out on small scale. A few farmers and farming institutes were experimenting manure digestion.
In 2004 and 2005 the climate towards co-digestion of manure was changing in The Netherlands. Until 2004, co-digestion in combination with reuse of digestate as fertiliser was not allowed. In June of that year the Dutch “positieve lijst”(positive list) was presented. Agricultural products on this list could be used for co-digestion without excluding the use of the digestate as fertiliser. A financial stimulation of digestion was the subsidiary of green electricity produced from biogas. Since January 2005 for each kWh of produced electricity from digestion of manure a bonus of Euro 0.097 was given by the Dutch government. This bonus was really effective in stimulating co-digestion. During the last two years the number of co-digestion plants was increasing from less than ten in 2005 up to more than 50 at the start of 2007.

Due to this development the question can be made “is stimulation of co-digestion with respect to the PROBIOGAS project still necessary”.
Answering this question is not so easy because the Dutch agricultural sector varies from the north to the south. The South of The Netherlands can be described as a livestock intensive area. Because of these activities and the shortage of fields for reuse the manure this part has a surplus of manure. Digestion or co-digestion of manure will not solve this problem. Combination of digestion with other techniques to reduce the amount of manure could be one of the solutions for the surplus of manure in this part of The Netherlands. In the north of The Netherlands agriculture is more a combination of livestockfarms and arable farming so manure can be used within the area or manure from other parts of the country can be used.
The Dutch involvement with the PROBIOGAS project was to deal with the problems of manure in livestock intensive areas of the country and to stimulate centralised co-digestion of manure more national wide.

The Dutch part of the PROBIOGAS project was coordinated and carried out by SenterNovem. SenterNovem is a governmental organisation (part of the Dutch Department of Economic Affairs) is involved as the Dutch partner in the EU-PROBIOGAS Project.
This report presents an overview of the PROBIOGAS activities in The Netherlands. The following issues are presented:

- The Dutch case
- The National Target Group
- Description of the dissemination activities
- Results
- The future of anaerobic digestion in The Netherlands

The Dutch case

SenterNovem has a good view on most projects concerning digestion of manure in The Netherlands and was involved in the BRK-project and presented this project as the Dutch case.
Near the city of Eindhoven, the region “de Kempen”, see figure 1, is an area with intensive agricultural activities (pig, cattle and poultry). It is not possible to reuse the produced manure as organic fertiliser within the area.

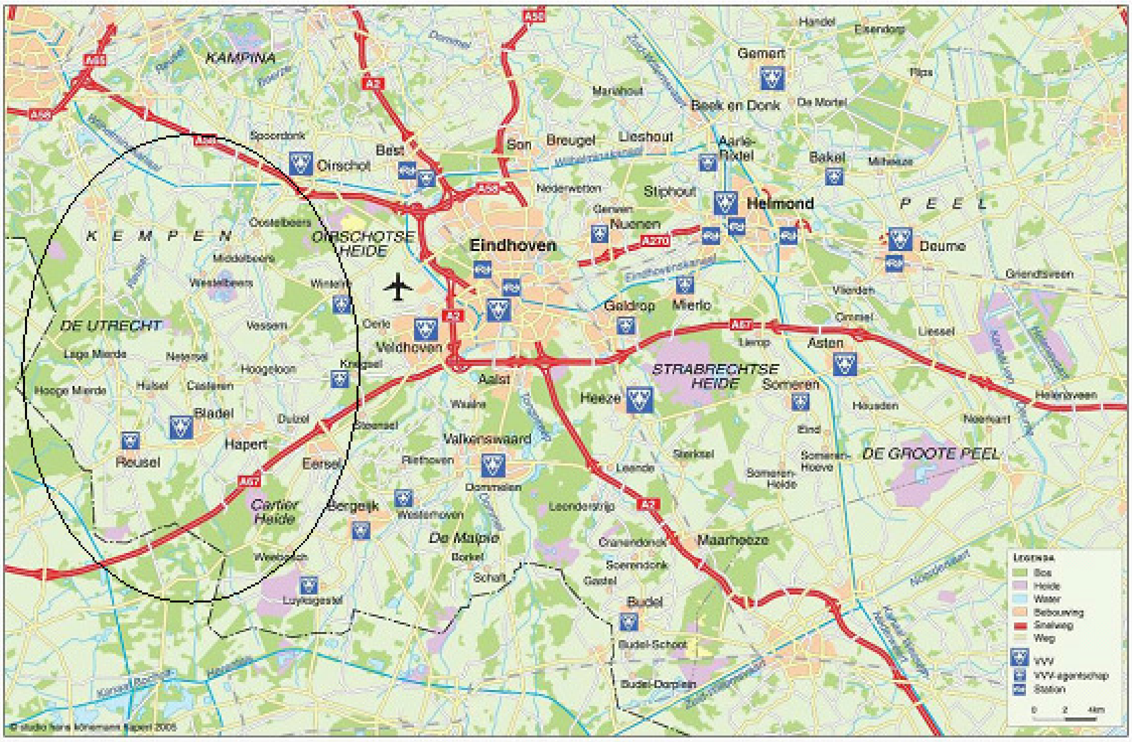


Figure 7.22. Area of the Kempen (circle)

A surplus of at least 1 million tons has to be transported to other regions. In order to reduce the costs of manure disposal, a group of farmers has founded the “Bio-Recycling de Kempen” (BRK). The BRK has plans to build and operate a plant for the treatment of manure. The process of manure treatment by BRK will be a combination of separation and digestion of manure. The aim of the project is to find a way of using the digestate outside agriculture because of a surplus of minerals in the area and a lack of agricultural area in the region (communities of Bladel, Reusel-Miersen and Hilvarenbeek).

Primarily the process will take place in two steps:

- a separation in two fractions: a solid one and a slurry
- the solid fraction will be transported to regions where there is a lack of manure (Province Zeeland – 100 km to the West)
- the slurry will be treated in the digester
- The digestate will be dewatered and the aqueous fraction will be treated in a (biological) water treatment process (to remove nitrate).

In the first stage of the plant, slurry of both pig and cattle manure will be mixed and separated in a thin and thick fraction. The thin fraction will be treated in an aerobic purification plant (dephosphation and denitrification). In the next stage the thick fraction will be digested in combination with poultry manure. The total capacity of the plant is estimated at 255.000 ton manure (cattle, pigs and hens/broilers) annually. Roughly divided in 200.000 tons of cattle and pig manure and 55.000 tons others (hens/broilers). Since June 2006 several farmers, which produce a total of 200.000 tons of manure, have joined the BRK.

The National Target Group

At the start of the project the National Target Group (NTG) was established. This group was involved in the process of collecting the data for the assessment study.

Participants of the NTG were from the BRK, SenterNovem and local authorities (SRE).

The first activities of the NTG focussed on the BRK-project itself. The primary aim of this incentive was manure treatment by separation without digestion. We came to the conclusion that a combination of manure treatment and digestion could be more profitable and sustainable. The extra produced heat of the combined heat power plant (CHP) could be used within the process.
The aim of the BRK initiative as Dutch case for the PROBIOGAS project is to find out if the Danish expertise can influence the choice of process and the technology which the BRK can choose for the best performance (both economical and environmental).
On the 6th of June 2005 the National Target Group had a meeting in Eindhoven in the office of the SRE (Environmental agency region Eindhoven).
The aim of this meeting was to inform the partners of the PROBIOGAS project. Two Danish experts joined this meeting and presented the PROBIOGAS organisation and the activities. To get informed about the situation of anaerobic digestion in Denmark Lars H. Nielsen from the Risoe National Laboratory in Denmark presented "The Centralised AD Plant Concept Economics and Externalities".
The main conclusion of this meeting was that the information required for the dissemination activities is available.
During the PROBIOGAS project it became clear that the realisation of the BRK project was doubtful. In order to use the Danish experience for the development of centralised anaerobic digestion in The Netherlands the focus of the PROBIOGAS project was shifted to a more national approach and the members of the NTG were individual involved in the process of stimulating co-digestion in The Netherlands.
To inform and stimulate farmers, farming organisations and local authorities about the possibilities of co-digestion of manure several meetings and workshops were organised. On several occasions members of the NTG were invited to join meetings to discuss the problems concerning manure digestion.

Description of the dissemination activities

The dissemination activities can be divided into general dissemination of centralised anaerobic digestion in The Netherlands and in particular the BRK incentive.
On several occasions the activities of the PROBIOGAS Project were presented on workshops and seminars in The Netherlands.

- 22 September 2005, Congress and workshops "large scale digestion of manure" with more than 150 visitors. The items discussed were: international experience in Denmark and Germany, the Dutch attitude with respect to manure disposal and environment.
- Several excursions to digesters have been organised and documentation presenting the development of anaerobic digestion is published. This report will inform farmers and project developers of digestion incentives. Several aspects "from idea to operational digestion plant" are presented.

- 2 October 2006, Congress and workshops "co-digestion of manure". More than 200 people visited this congress although the government stopped subsidizing sustainable electricity per the 17th of August 2007. During one of the workshops the interim results of the assessment of the Dutch case study were presented. One of the main aspects was that digestion of manure could only be economically feasible if co-products (organic waste) could be added to the digestion process.
- January 2007, Evaluation of the activities of the Dutch programm "Kennis van collega's" As a result of the existing problems concerning the process of legislation of anaerobic digestion incentives SenterNovem started a programm to support government employees during the process of preparation of permits for digestion plants. The last two years more than 25 incentives were supported and the time needed to get the permits could be reduced.

- In October 2006 the report “Kansen voor duurzame co-vergisting” (changes for sustainable co-digestion) was published. This report presents the development of anaerobic digestion in The Netherlands with special attention towards regional differences. (Northern part – farm scale digesters, east and southern part of The Netherlands – collective incentives of digesters).

Results and impact of the PROBIOGAS project

The results of the assessment of the Dutch case by the Danish experts can be summarised as follows. The significant manure surplus situation in the North– Brabant region in The Netherlands form excellent preconditions for centralised anaerobic digestion plants (CAD plants) in this region (see figure 1). Farmers would largely benefit economically as they may achieve considerable cost savings in transport, as the CAD plant is assumed to take over transport costs for surplus manure export to other Dutch regions. Receivers of surplus digested manure benefit from cost savings in fertiliser purchase. Relative high dry matter contents in the manure forms a large potential for biogas production. However, the estimates for the economical performance of an imaginary CAD plant in the region, based on the assumptions made, shows that the system is not economically feasible by the existing preconditions. Three main reasons for the relatively poor economic performance can be identified as the most important barriers for an enlargement of CAD plants in The Netherlands:

- No waste application is allowed
- Relatively low electricity price
- No market for the heat.

Part of the study was a socio economic analysis of the CAD plant which looks at the biogas-scheme from the point of view of the society at large. Therefore all consequences of the scheme in any sector of society should in theory be taken into account - including externalities. Biogas projects have implications not only for the agricultural sector, but also for the industrial and energy sectors. For the environment, mitigation of greenhouse gas (GHG) emissions and e.g. eutrophication of ground water etc. are important external effects. In this study, efforts have been put into the quantification and monetization of some of the biogas scheme externalities. Several levels are included in the analysis where the base level does not include any externalities, and the top level includes all quantified and monetized externalities.
If all the socio economic aspects are taken into account CAD plants in The Netherlands could be profitable. But it should be considered that the socioeconomic analysis does not show the profitability from a business point of view, but it shows the profitability from the society point of view, which means that its results can be used as input and arguments in developing agricultural, energy and environmental strategies.

During the realisation of the PROBIOGAS project the feasibility of manure digestion has changed. At the start of the project, in January 2005, the Dutch government was subsidizing sustainable electricity. Producers of electricity from biogas could get a bonus of 97 Euro/MWh. On the 18th of August 2006 the government stopped subsidizing sustainable electricity. This means that new incentives for digestion of manure can no longer take advantage of this subsidy. This had a large effect on the growth of new digestion plants in The Netherlands. In the period 2005-2006 about fifty new digestion plants became operational and several were under construction (see Figure 7.23).

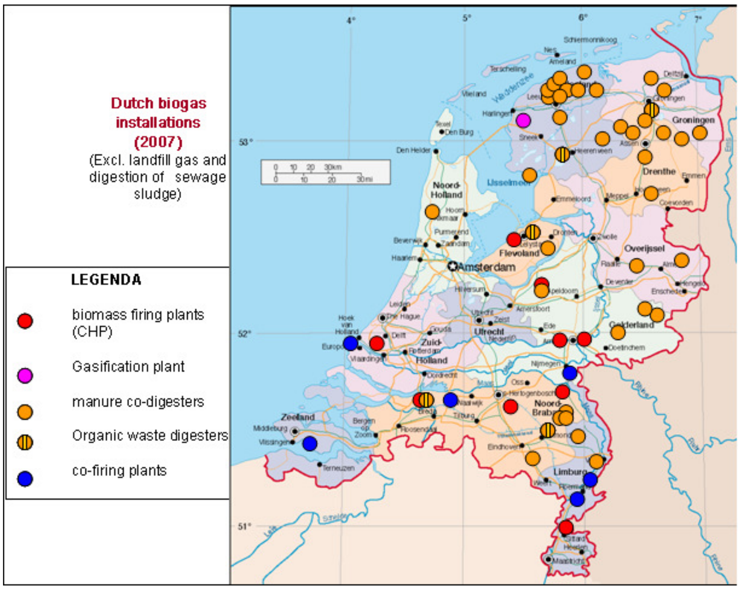


Figure 7.23. Number and location of bio energy production unit in The Netherlands (April 2007)

Farmers and project developers came to the conclusion that without increasing the efficiency of the digestion process and finding a way to monetise the surplus of produced heat digestion plants could never be profitable. This confirms the conclusions of the assessment study of the Dutch case.

As said above during the realisation of the PROBIOGAS project the awareness of digestion of manure and organic waste in The Netherlands was great. As a result the list containing the organic products which are allowed to digest in combination with manure has been extended since the introduction of “the positive list” in July 2004.

Due to the experience with digestion of organic waste in Denmark and the impact, (increase) of the biogas production the extension of the positive list is still an important issue in The Netherlands.

Apart from the economical aspects local conditions are of importance during the process of realizing a digestion plant. The incentive of the BRK is still in the process of development because of problems finding a suitable location for the plant. Especially large digesters have to deal with these problems. Not only the acceptance of a large digestion plant on a local industrial park is a problem but also the high price of industrial land, compared with the price of a location near a farm.

Nevertheless on several locations throughout the country farmers did succeed in realising digestion plants with a capacity up to 50.000 tons a year. Compared with the size of the CAD plants in Denmark they are rather small but it is just a start.

Important lessons from the PROBIOGAS project are:

1. Expertise and experience concerning centralised digestion from other countries can be useful but one has to be aware of the local and national aspect. For example the surplus of manure in The Netherlands requires a special approach. In Belgium and Ireland the conditions are similar compared to The Netherlands.
2. The local and national approach towards digestion may differ from place to place or within the local authorities. Starting a discussion on the main problems with the stake holders is useful.
3. Do not focus on one particular project only but create a fall back scenario. The BRK incentive had to deal with a big problem; finding a suitable and reasonably priced location. Using the knowledge of the PROBIOGAS assessment within other incentives the results of the PROBIOGAS project are more effective in process of stimulating centralised anaerobic digestion in The Netherlands.
4. If centralised digestion in The Netherlands is difficult a focus to farm scale digestion may be a solution to get digestion accepted. (During the realisation of the PROBIOGAS project more than 50 farm scale digesters have become operational – digestion capacity 1.0 to 1.5 million tons/year – 35 MW installed electrical power).

5. Instead of identifying only the financial and technical aspects of an anaerobic digestion plant the socio economical and non technical aspects have become more important. The discussion of the reduction of greenhouse gasses due to digestion and the use of digestate as a replacement of fertiliser has started in The Netherlands.

The future of anaerobic digestion in The Netherlands

Large Scale Digestion in The Netherlands – After PROBIOGAS

Despite of the results of the Danish analyses realisation of centralised large scale co-digestion plants in The Netherlands is still difficult and taking time. The economical feasibility has become worse because of the change in subsidizing green electricity since August 2006. Therefore at this moment all new incentives for co-digestion in The Netherlands are put on hold and are waiting for a new system of stimulating sustainable energy (electricity-heat-green gas).

At this moment the sustainability of the use of several types of biomass is under discussion including the use of energy crops for digestion.

The results of the PROBIOGAS project and the expertise of the Danish experts will be of use in the future. On several locations in The Netherlands farmers and other organisations or project developers are planning new digesters including some centralised anaerobic digestion plants.

Other activities concerning co-digestion in which SenterNovem will be involved in the years 2007 and 2008 are:

1. The PROBIOGAS is not concerning the Dutch case only; presenting this project on several occasions has stimulated the development of digestion in The Netherlands. Several organisations became more interested in the Danish experience concerning co-digestion of waste. The results of the assessment study will be discussed within the Dutch government in order to achieve a more open mind for the digestion of organic waste in combination with the use of digestate as a fertiliser.
2. Especially concerning digestion raising the efficiency of digestion by creating better combination of production of electricity in combination with the use of heat (a problem in most cases) or the upgrading of biogas to natural gas quality is very important. As an example of raising the efficiency (and CO_2 reduction) of digestion the latest development in The Netherlands is to use biogas for local district heating or to upgrade the biogas to natural gas quality. In June 2007 as a part of the "greengas project" a workshop was organised to investigate the aspects of injecting upgraded biogas in the Dutch natural gas grid. The aim of this project is to solve the possible problems and to start experimental projects in order to find out quality standards for upgraded biogas.
3. Non technical barriers are a big problem in the development of digestion in The Netherlands. Discussions with local authorities and the presentation of the situation in Denmark and Germany were of great importance to get more understanding for digestion of manure and the local effects. The activities of supporting the local government will be continued as it seems to be very effective in optimizing the process of legislation of bio energy incentives (specially concerning digestion plants). At this moment SenterNovem is involved in the legislation process of several farm scale digestion plants (max capacity up to 36.000 ton per plant). Support the development of co-digestion both farm scale and centralised by means of attending meetings, presenting information and informing the stakeholders regularly by mail (including the BRK initiative).
4. SenterNovem is involved in several platforms to stimulate sustainable energy and in particular bio energy in The Netherlands and Europe.

Conclusions

It can be concluded that large scale co-digestion of manure in The Netherlands is still difficult. The increase of the number of small-scale plants during the last two years has shown that co-digestion is an excepted technology in The Netherlands. The subsidizing of sustainable electricity was the main driver of this development. In the future digestion, in combination with manure/digestate treatment will develop in The Netherlands in order to deal with the surplus of manure livestock intensive areas of the country and the need of producing sustainable energy. Dissemination of the Danish expertise as a result of the PROBIOGAS project had impact on the discussions in The Netherlands concerning the use of organic waste as a co-product for digestion. For the future the Danish experience on digestion processes will help the development of anaerobic digestion in The Netherlands.

As said before many activities of SenterNovem are concerning the stimulation of sustainable energy in The Netherlands. Below a short list of documents which deal with the production of sustainable energy from anaerobic digestion processes:

- Upgrading biogas to natural gas - May 2007
- Fact sheet: Energy production from energy crops, wood and manure in Noordoost-Brabant - May 2007)
- Examples of bio-energy from industrial organic waste - May 2007
- Feasibility of biomass fired CHP - May 2007)
- Biomass fuel trade in Europe, Summary Report - March 2007
- Green Gas - March 2007
- Sustainability co-digestion of manure - February 2007
- Status document bio-energy in The Netherlands - December 2006
- Chances for sustainable co-digestion - October 2006)
- External delivery of heat from biogas combustion - July 2006
- Handbook permits co-digestion of manure - July 2005 (updated in August 2007)
- An inventory of the heat demand of biomass fired CHP - March 2003

The Dutch version of these documents can be downloaded from the website of SenterNovem
http://www.senternovem.nl
http://www.senternovem.nl/duurzameenergie/Publicaties/index.asp

8. Working together with Target Group Networks (TGN)

The accomplishment of large biogas projects is very complicated and involves a range of main actors, persons, organisations and authorities. It is important that each one of the parts involved in a biogas project realise the potential in the project for his specific interests. This shows the need for a variety of members of the target group.
The target group network that was established at the beginning of the project was interacting with the national partners throughout the project, helped procuring necessary data and received information and results from the project. The idea was that the network would form the future co-operation platform for the initiation of a biogas project in that region.

When selecting the target groups for this project the main focus was on following groups:

1. Local, regional and national policy makers.
2. Local and regional authorities
3. Local, regional and national energy and energy trade companies
4. National energy and environmental agencies
5. Local farmers, farmers' extension service, farmers associations
6. Local food processing industries

The national partners were the key actors in the formation of the target group networks. Relevant biogas actors from all of the above categories, but also biogas experts and scientists, were included in the target group networks and invited to the introductory workshops organised in each one of the selected case study areas.

Through the creation of the TGNs close contacts with involved parties have been established. These contacts resulted in the identification of the various categories of the "key players" and the determination of the planning networks. The main contacts have been made with local farmers, SMEs, technology suppliers, specialized contractors, equipment manufactures, financing providers, policy makers (Ministries, Local Authorities) etc.

Complete lists of the members of the six TGNs are available at the project web page: **www.sdu.dk/bio**.

9. Assessment results of the selected case studies

The assessments of the six case study regions have analysed the potential of biogas production and the economic and environmental impact of building a biogas plant for centralised co-digestion of animal manure and other suitable biomass originating from the region.

The assessment work is based on the interaction between the national partners and their target group networks on one side and a core group of Danish experts on the other side, who actually carried out the assessment work.

Only main results of the assent work are presented in the present report. The full text of the national assessment reports and the final assessment report are available for free download at **www.sdu.dk/bio**.

General considerations

The environmental consequences of fossil fuels based energy and transport as well as inefficient manure management in the agricultural sector brings about serious challenges to find alternative sustainable solutions. The emission of greenhouse gases from these sectors are suspected to be responsible for the increased global average temperature and the extreme weather conditions, occurring more often than ever before.

Production of renewable, clean energy can substitute fossil fuels, hence moderating the environmental impacts caused by fossil energy production. A further reduction in the greenhouse gas emissions can be realised by integrating renewable energy production and advanced manure management. This can be done by many ways, of which one is the centralised co-digestion of animal manure and other suitable digestible substartes.

Centralised anaerobic co-digestion technology has been developed in Denmark since the early 1980s. This development was carried on through public development and monitoring programmes, investment grants and research funding. Considerable experience concerning plant operation, process control and plant economy has been collected, analysed and disseminated through these programmes. A study carried out in 2002 concluded the experience and knowledge gathered by the above programmes and the report published with this occasion, assessing the best-practice-model biogas plants from the economic, socio-economic and environmental point of view, quantified and monetized for the first time all relevant externalities of biogas from centralised co digestion.

The publication of the report revealed a great demand for similar assessments in other European countries but the Danish method and results were not directly applicable to other cases.

This is why the PROBIOGAS project was formulated, aiming to respond to the need of assessing the impact of biogas from centralised co-digestion in selected areas of six European countries. The results of the assessment show the socio economic impacts and benefits of biogas, help identify and remove the existing non-technical barriers and provide incentives for the implementation of biogas systems in these areas.

The aim of the project is to transfer best-practice experience on centralised anaerobic co-digestion plants in Denmark to other EU countries and by this to increase the awareness about the perspectives of this technology and to support the development of biogas production for heat and electricity in the European Union. The project also aims to identifying the non-technical barriers, in each participating country, which need to be addressed if biogas production is to increase in each of the countries.

A socio-economic analysis is included in the assessments. This analysis can be used by governments when considering which strategic measures to implement, for example in future energy planning and green house gas emission (GHG) reduction policies.

The project is accomplished as a co-operation between partners in seven EU countries. The countries in which the assessments of case studies were made include: the Netherlands, Belgium, France, Ireland, Spain and Greece. A national partner from each of these countries worked in co-operation with a group of Danish experts to accomplish the project.

The following institutions were involved:

Table 9.1. The role of the plants

Institution/company	Country	Role in the project
University of southern denmark	DK	Project coordinator
Institute of food and resource economics	DK	Economic assessments
Faculty of agricultural sciences	DK	Mass balance, ghg emissions
Danish agricultural advisory service	DK	Nutrient utilisation
Risoe national laboratory	DK	Socio-economic assessments
Senternovem	NL	National partner
Walloon agricultural research center	B	National partner
Solagro	F	National partner
Methanogen ltd.	IRL	National partner
University of barcelona	E	National partner
Centre for renewable energy sources	GR	National partner

In each of the countries a livestock intensive area was selected for each case study.

The Danish experts elaborated a data template, to be filled in by the national partners with local and national data for each case study. Each case study was assessed, in relation to its economic, agricultural, energy and environmental effects. The results are presented in a national report for each case study and in a final assessment report, which outline the main results and conclusions of the whole project.

Results may be used to evaluate the perspectives of CAD technology in each national context, as they are, where possible, based on existing national preconditions. Legal restraints and other inhibitive barriers have been exposed, and recommendations made on what can be done to encourage the implementation of CAD plants, in the national partner countries.

The assessments are based on analysis models developed under Danish circumstances. The results of the assessments can be used to inform a future feasibility study for each case. Assessments undertaken in PROBIOGAS must be followed by detailed technical, economical and organisational planning before a construction phase is eventually initiated.

A socio-economic analysis is carried out as a cost-benefit analysis. The cost benefit analysis is different to corporate economic analyses, and may not be used as such. Results from this socio-economic analysis show the performance of a CAD system from the society's point of view, and can be used when considering which strategic measures to implement, for example in future energy planning and GHG emission reduction policies.

The PROBIOGAS project was implemented by an introductory seminar held in each one of the national partner countries once the case study area had been selected, by the national partner. Invited to the seminar were farmers and companies from the case study area, and both local and national organisations and authorities. In fact all parties were invited, who would be involved in the realization of a CAD, if a real project was to be initiated later. The participants in the seminar were asked to form a project network (TGN), chaired by each national partner. The members of the TGN were asked to be involved in the project activities and to be the main target group for the dissemination of the project results.

The national partner collected the data required for the analysis with the assistance of the TGN members, by visiting farms and contacting organic waste producers in the case study area, and by other research. Unfortunately not all the background data concerning national costs and future predictions that were necessary to inform the assessments was available. Where it was not available, values used throughout EU or from Danish research, were utilised.

The assessments made by the Danish experts included

a) Energy production and economic performance of the CAD.
b) The effects on farms,
c) Changes in nutrient utilisation
d) Changes in green house gas emissions
e) Changes in odour emissions
f) The socio-economic effect on society from the derived benefits of the CAD

The Danish experts elaborated a questionnaire, which was completed by the national partners, with the assistance of the TGN. The purpose of the questionnaire was to identify the non-technical barriers for the implementation and development of CAD in the studied areas. The Danish and national partners then jointly developed some solutions to propose to the TGN members, as inspiration for the TGN and to motivate national authorities to remove the non-technical barriers currently prohibiting CAD development in these EU countries.

The PROBIOGAS project has provided answers to questions like: Why do we need CAD? Do farmers benefit? Is CAD beneficial to the environment? What other benefits are there? What is needed to make a CAD viable?

Technical outline of the model centralised co-digestion plant (CAD)

There are two main parameters that determine the dimensions of a CAD plant. These are the amount and quality of manure and waste supplied to the plant. These determine the size (capacity) of the CAD and the biogas production produced by it. The amount of manure and organic waste identified in the case study areas by the national partners, varied from 34,000 to 220,000 tonnes on an annual basis, equivalent to 93-600 tonnes per day. Therefore the capacity of the CAD plants in the national case studies ranged from 1400 to 9000 m^3

The CAD design used for the model is operated at thermophillic temperatures, which means 52-55^oC, and has a 15 days retention time. The plant is equipped with 70^oC pre-sanitation step, heat exchanging, biogas cleaning facilities, odour control system, storage vessel for biogas and combined heat and power plant (CHP) plant for heat and power production. Figure 9.1 shows a diagram of the CAD design.

The manure and organic waste is unloaded in an unloading hall into the pre-storage tank. From there it is pumped to the mixing tank in which the biomass is properly stirred and is of a sufficient size to obtain the optimal composition of feedstock for the digester. From the mixing tank the biomass is pumped to one of the sanitation tanks through the heat exchangers. The heat exchangers are designed to allow heat to be recovered from the material when unloaded from the sanitation tank and from the digested manure when unloaded from the digesters.

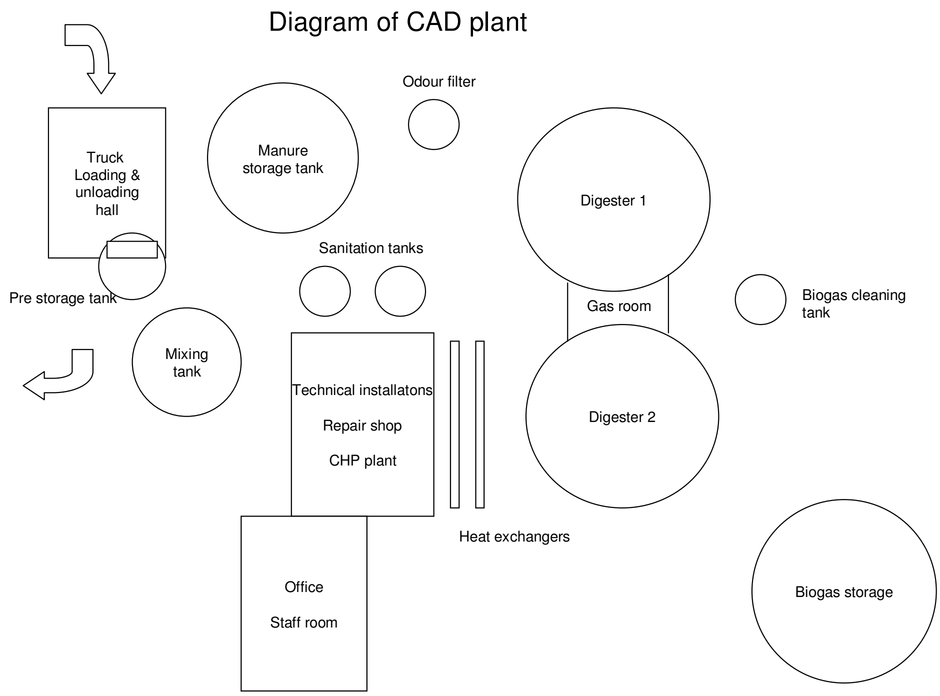


Figure 9.1. Diagram of the CAD plant. Source: P. Thygesen

After sanitation the material is pumped through the heat exchangers again (to reclaim some of the heat), and into the digester(s) where the anaerobic degradation process takes place and from which biogas is produced. After 15 days in the digester, the now digested manure is unloaded and pumped through the heat exchangers into the manure storage tank, for the last time. From the storage tank, the manure is loaded on to trucks and returned to storage tanks at the farms.

The biogas is cleaned in a biogas cleaning tank by a biological process and sent to the CHP plant for conversion into heat and power. The electricity production capacity of the CHP plant varies depending on the quality and amount of biogas produced and the efficiency of the CHP. The efficiency of the CHP in the case study is 36% electricity and 54% heat. The quality and quantity of biogas produced depends on the amount, type and quality of the material digested.

Odour emissions produced at the CAD plant are controlled by sucking away air from the unloading hall, the pre-storage and mixing tanks, and cleaning it in a biological odour filter.

Capacity, inputs and outputs for the CAD in the national case studies

There are considerable differences in CAD plant sizes between the national case studies due to the difference in treatment capacity ranging from approx. 93-600 tonnes biomass per day. Almost the same difference is found in estimated methane production. Therefore, the heat and power production from the different CAD plants also varies. Table 9.2 shows main input and output data for the six case studies

In the Dutch, Spanish and Greek case the surplus heat cannot be utilised, but in the French, Belgian, and Irish case heat is utilised for industrial and/or house heating purposes.

Table 9.2. Main data

	F	IRL	SP	GR	B	NL
Treatment capacity tonnes/year	43800	52400	167800	34000	75000	220000
Treatment capacity, tonnes/day	120	144	460	93	200	600
Biogas production, mil m^3 CH_4/year	1,6	1,1	4,4	1	1,5	6,4
Electricity production, MWh/year	5900	4000	16000	3700	5500	23000
Heat production, MWh/year	7500	4600	22800	5200	7900	34000

The variance in biogas production depending on the type of feedstock processed can be seen from table 9.2. For example in the Belgian case more than twice the amount of material is processed compared to the Greek case, but the gas production is only 50% greater.

Biomass resources, mass balances and methane yields

Both amount and composition of biomass resources, supplied to the plant in different case studies, vary significantly from 34,000 to 220,000 tonnes. The biomass resources are listed in Table 9.3. The main categories of biomass processed are manure from cattle, pig and broilers poultry. The proportion of waste supplied varies from 0 >50%, depending on the case study. Figure 9.2 illustrates the composition of the total biomass supplied to each plant. Only organic wastes that required no further technical requirements before processing in the digester and that are suitable to be spread on farm-land afterwards, have been used in the calculations.
The biogas production has been calculated by using specific CH_4 yields from the actual organic solids (VS). Mass balances have been calculated by assuming that no nutrients are lost during the biogas process, and that 50% of the organic nitrogen is converted to NH_4-N.

Table 9.3. Main biomass resources

	F	IRL	SP	GR	B	NL
Manure, tonnes/year	37711	34372	163890	16700	58391	220000
Organic waste, tonnes/year	6067	18000	3850	17230	16600	0
Total amounts supplied, tonnes/year	43778	52372	167740	33930	74991	220000

Furthermore the dry matter (DM) and (VS) content in the biogas output is calculated by subtracting the amount of VS converted to gas from the input by assuming that 2 kg VS from manure and non fatty wastes, and 1 kg VS from fatty wastes is converted for each m^3 CH_4 produced. Total methane production is showed in Table 9.4.

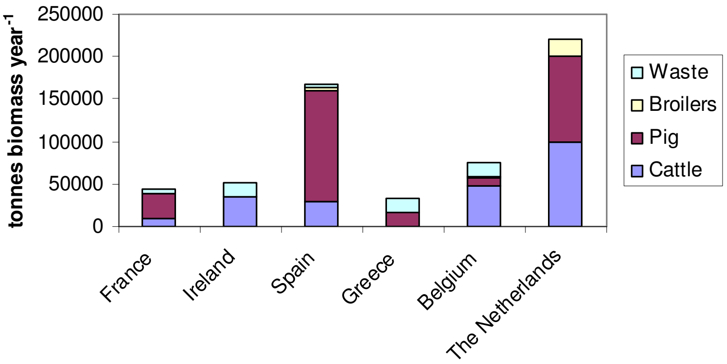


Figure 9.2.. Amounts and types of biomass added to the plants in the different countries

Table 9.4. Methane production and methane yields

	F	IRL	SP	GR	B	NL
Manure, tonnes/y	37711	34372	163890	16700	58391	220000
Methane production, m^3 CH_4/y	1633505	1112657	4443144	1024520	1530265	6408000
Methane yields, m^3 CH_4/m^3 biomass	37	21	26	30	20	29

Table 9.4 shows considerable variation in methane yields achieved in the individual CAD plants from the different case studies, due to the variance in the type and quality of the manure. For example in the French case, where the addition of high yielding fatty wastes contribute significantly to the total production, or in the Dutch case where no waste at all is supplied, but a large proportion of the methane production derives from poultry manure.

The methane yields vary, between case studies, from 1 to 6.4 million m^3 of methane per year and 20 to 37 m^3 CH_4 per tonne biomass supplied to the CAD. Methane yield is an important figure when it comes to economic and socio-economic performance. Therefore the quality of manure and waste with respect to methane production potential is very important.

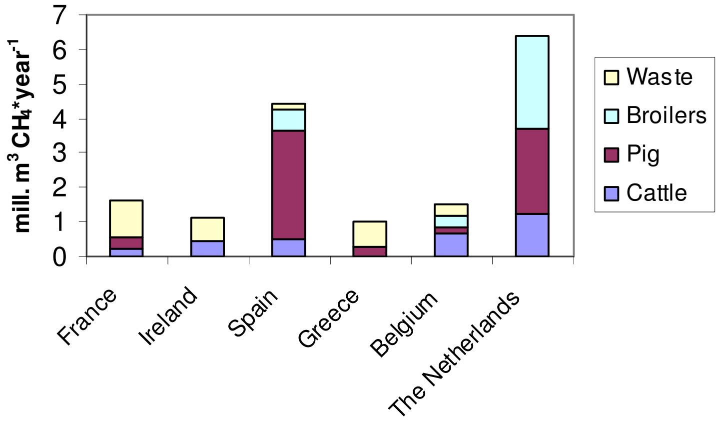


Figure 9.3. The yield of methane from the different biomass sources in the different countries

The DM content and the methane yields in terms of tonnes of biomass is illustrated in Figure 9.4. The dry-matter content varies from 7 to 12%. The highest dry-matter concentrations are in the upper end of what can be handled in a completely mixed digester of the design used in this analysis without special technical precautions.

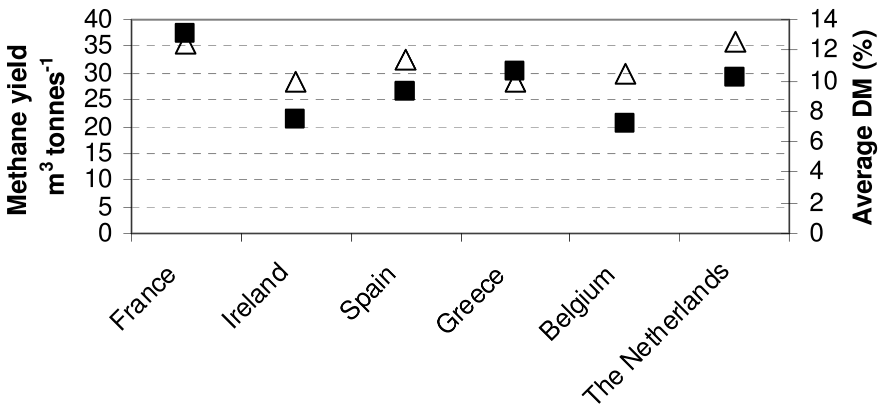


Figure 9.4. Methane yield and the dry-matter concentration in the biomass for the different countries. ■ methane yield in m^3CH_4/tonne, Δ the average dry-matter DM (%).

The figure indicates high correlation between average dry matter content and (theoretical) methane production. However the quality of dry matter is also different. Deep litter or solid manure with large amounts of straw is not quite as productive of methane as wastes with fat, oil or sugar.

Agricultural and nutrient effects

According to common sense and good agricultural practice, manure should be utilised as a fertiliser on the fields. Digestion of manure in a biogas plant has a substantial effect on the fertiliser value of the manure. The composition and the fertiliser effect of digested slurry are changed compared to the untreated pig or cattle manure the farmers normally on the fields. There are at least three reasons for that:

1. Organic material (including organic nitrogen) is broken down in the biogas process, and the amount of plant available nitrogen (ammonium) is increased.
2. At the biogas plant pig slurry, cattle slurry and solid manure are mixed
3. A substantial amount of industrial waste is added (adding nutrients)

These changes must be considered when making fertiliser plans on the farms receiving digested products from the biogas plant. If this is done, then a significant saving on buying mineral fertiliser can be realised, as well as reducing the negative impact on the environment.

Method

For all farms receiving digested manure from the biogas plant, the area of each type of crop currently grown, is summarized. The related crop demand for nitrogen, phosphorus and potassium is calculated for the total of land that will receive digested manure, according to the general fertiliser recommendations for the region. The amount of additional mineral fertiliser required is calculated by subtracting the advised fertiliser value of the digested manure from the total crop demand for nutrients on the case study farms.

The farms that supply manure to the biogas plant, receive back digested manure. The amount they receive depends on the nutrient need for their farm. If the requirement for nutrients is greater than the amount of nutrients in the manure sent to the biogas plant and if there is surplus digested manure (arising due to adding organic waste) available, they would receive additional digested manure up to the amount of nutrients required for the crops on the farm. If the requirement for nutrients is less than the amount of nutrients in the manure sent to the biogas plant, then they would receive less digested manure than raw manure sent. The amount of financial benefit for the farms that supply manure to the biogas plant is calculated to be the total saving in purchases of artificial fertiliser over all farms gained by being part of the biogas case study.

In the assessments digested manure, that is surplus to the requirement of nutrients on the farms supplying manure to the biogas plant, is "exported" to livestock or crop production farms that are not supplying manure to the biogas plant. It is assumed that the exported digested manure will all be used to replace mineral fertiliser. Therefore the benefit per hectare for land that receives digested manure appears to be much higher than on farms that are replacing raw manure with digested manure.

The area of land required to receive all the digested manure is calculated by assuming that a full utilisation of phosphorus in the surplus manure can be obtained, without exceeding national regulations and requirements.

The fertiliser effect of nitrogen in untreated manure and digested slurry is assumed to be a full utilisation of ammonium (except for Ireland where utilisation is taken to be the level of utilisation 20% advised for slurry in 2005). In practice this fertiliser effect can only be obtained by an optimal use, according to spreading time, spreading method etc. and will require a sufficient storage capacity, which normally would require a capacity to store the manure for 6-9 months.
Table 9.5 shows the estimated effects on nutrient utilisation and fertiliser purchase.

Table 9.5. Estimated effects on nutrient utilisation and fertiliser purchase

	F	IRL	SP	GR	B	NL
Suppliers of manure (and receivers)						
Manure and organic waste/y, tonne	43778	52372	167740	33930	74991	220000
Digested manure spread in the area/y, tonne	33448	48802	25275	1400	52791	0
Savings mineral fertiliser, EUR/y	15895	40262	0	0	16890	0
Saved mineral fertiliser, kg N	21480	39447	0	0	30028	0
Saved mineral fertiliser, kg P_2O_5	0	16941	0	0	-2265	0
Saved mineral fertiliser, kg K_2O	0	656	0	0	-5164	0
Receivers of surplus manure						
Surplus digested manure received	10330	3570	142465	32530	22200	220000
Saved mineral fertiliser EUR/y	62929	-19154	160027	76144	65569	307797
Saved mineral fertiliser, kg N	39687	9152	197656	44096	42657	412535
Saved mineral fertiliser, kg P_2O_5	31368	16929	1628	26570	37293	0
Saved mineral fertiliser, kg K_2O	35281	1762	2411	26650	70485	0
Total savings, mineral fertiliser, EUR/y	78824	21109	160027	76144	82459	307797
Average savings per hectare, EUR/y	53	5	-	-	27	25

The effects are estimated as the difference between the situation without a biogas plant and the situation with a biogas plant. Effects and savings derive from the above mentioned parameters. The Dutch situation is special, as only surplus manure is supplied to the plant, so manure producers do not benefit from the fertiliser value improvement, which therefore entirely goes to the receivers of the surplus manure. The Spanish and Greek situations are also special, as only little manure can be used locally, and no market for it is found outside the region. Thus the savings in theses cases should rather be seen as an increase in the potential for utilisation of nutrients in each of the case studies. In the Spanish case an unrealised fertiliser value of 1.1 mil EUR has been estimated, and in the Greek case this figure is 145,000 EUR.

In two of the remaining case studies, Belgium and France, both manure producing farmers and digested manure receivers benefit from improved fertiliser values. The Belgian and French case studies show cost savings from 27-53 EUR per hectare. In the Irish case study a relatively low nitrogen utilisation rate has been used in the estimates due to national recommendations, for slurry at the time. If this rate was based on Danish experience fertiliser values would increase for the Irish case study from 20 to 100% of ammonia N.

Effect on green house gas emissions

Some of the environmental hazards that may be related to animal manure management are GHG emissions, ammonia emissions, odour and nitrate leaching. GHG can be efficiently reduced by processing manure in a biogas plant. Studies have shown that ammonia emission may be higher during storage of digested manure, but that simple covers can mitigate that problem (Sommer 1997). Ammonia emission from slurry after spreading is not affected by digestion of the slurry (Rubæk et al. 1996). Odour may be reduced by anaerobic digestion especially if the biogas plant is properly built and emission of gases from the plant reduced with air filters etc. Leaching and erosion losses of nitrogen and phosphorous can be reduced by achieving a more efficient use of nitrogen in manure and a better distribution and use of nutrients after the manure is digested.

Measures to reduce global warming due to the greenhouse effect tend to focus on CO_2 emissions from combustion of fossil fuels. In comparison, the amounts of CH_4 and N_2O emitted to the atmosphere are low, but their global warming potentials are, respectively, 21 and 310 times higher than that of CO_2 (IPCC 2001). Therefore, a reduction in methane and nitrous oxide emission may significantly contribute to reduce global warming. One of the objectives of this project was to assess the direct effects of anaerobic digestion on environmental hazards related to livestock farming and organic waste handling, in particular the emission of methane, but also nitrous oxide.

The effect of biogas production on methane is high (Sommer et al. 2004) and we have models that can be used globally to assess this effect. These models can take into account different management practices and differences in climate between regions.

For nitrous oxide the models for calculating the emission is very complex and with a high demand for input data. These data could not be provided within the frames of this project. Therefore it was decided to calculate how much biogas production reduced emission of N_2O by using a simple emission reduction factor derived from a recent Danish study where the GHG gas reduction potential of biogas production of manure was assessed (Sommer et al. 2004). This assumption is indeed very simple and models including local climate, soil etc. in the calculations may give different emission estimates.

Methane emission from animal slurry systems is calculated using the dynamic models of Sommer et al. (2004)

In the calculations of methane emission from the scenarios with biogas production, it is assumed that the management of manure during housing and outside is not changed significantly, i.e. emptying manure from houses, duration of storage time etc., apart from having included biogas production.

It is assumed that when using solid manure for biogas production the manure is afterwards stored as liquid manure after fermentation in the digester, as it is then mixed with liquid manure.

Likewise, effects on GHG emissions were estimated in the case studies from the remaining countries. The results from calculating GHG emission are presented in the following Table 9.6 More details about the calculations can be found in the national reports.

Table 9.6. The annual reduction in GHG emissions as a consequence of the anaerobic digestion in the CAD plant in each case study

	Reduction in tonne CO_2 eq. per year*					
	F	IRL	SP	GR	B	NL
CH_4: Animal manure	325	6,3	2161	834	219	7309
CH_4: Organic waste	628	183	95	1844	122	0
N_2O: Manure and waste	838	447	6365	465	507	6737
Total	1791	636	8621	3143	848	14046

*Methane conversion factor of 21 and N_2O conversion factor 310 (Derwent et al. 2002; IPCC 2001)

During the anaerobic digestion process organic matter is converted into biogas, which reduces the methane emission potential during the following storage period. This has been demonstrated in Danish trials. So when the manure management system in the reference situation is based on liquid manure, the AD process contributes to a reduction of GHG. However this is not always the case, if the reference manure management system to a large extent is based on solid manure or deep litter beddings. In these cases the reference GHG emissions would as mentioned be very limited, but as digested manure is normally stored as liquid digestate, GHG may increase somewhat from this part.

Table 9.6 shows considerable variation in GHG reduction potential among the case studies. Highest effect is mainly found in slurry based systems in areas with higher temperatures (NL, SP, GR), and of course storage time inside houses is important. Lowest effects were found in case studies where slurry was stored for long periods before being processed, or where relatively large amounts of solid manure is supplied, because of the comparative increase in emissions from post-storage of liquid digested manure, compared to aerobically storing the solid manure.

The biogas production can also produce GHG emission reduction, if used to substitute fossil fuels. More about that is found in chapter 10.

Economic results

The economic assessment calculations take into consideration the whole system related to the CAD plant, from the manure production to when the nutrients in the digested manure are utilised as a fertiliser in the fields. The farms that supply manure are included within the calculations, but the benefits for individual farms cannot be isolated. Only the effect on fertiliser value of digested manure returned to the supplying farms is included in the calculations. When more digested manure is produced than manure supplied or where the supplying farms cannot utilise as much digested manure as raw manure that they supply, the benefits from the fertiliser value in the surplus manure are considered as externalities. The benefits for the farmers whom are assumed to receive surplus manure are analysed in the chapters 7 and 10.

The calculations are carried out in an integrated spread sheet model based on Danish experience. Input data has been provided by national partners, concerning the input of manure and waste and sales prices for heat and electricity as well as treatment fees for the receipt of organic waste and transport costs and distances. Capital and operational costs are calculated in Danish 2005 prices in the first place, and then transformed to national 2005 prices, by using Comparative Price Parity Levels from Eurostat. Therefore the figures are presented at each national cost level, which makes each case study not fully comparable with others. As the price levels were consumer prices, they were adjusted for variations in VAT. The used interest rate is 5.5 % p.a.

Basic preconditions are highly variable among the six case studies carried out, which is in fact not at all surprising considering the difference between the participating countries. Differences in the preconditions in soil structure and fertility, climate, rainfall and in legal regulations concerning handling and application of manure are found. Such preconditions play an important role in the assessment of the overall performance of the system, and also effect farmers economically in different ways.

In Denmark the requirement of 9 months storage capacity was perhaps the most important driving force for farmers to initiate CAD plants from 1988-98. The CAD company made the investments and provided the capacity to farmers. Farmers would then not have to make the investments themselves, but they could rent the needed capacity in a flexible and favourable way. In addition some of the storage tanks were built in the area close to the fields, rather than in farm yards. By having the digested manure stored near the fields that will utilize it, spreading became a lot easier, as the distance between tank and fields is reduced. Effects like these are hard to quantify for a hypothetical CAD plant, so only a small allowance has been made in the calculations, although the potential savings may be greater.

Anaerobic digestion increases the availability of nitrogen in the manure. As the amount of manure that can be spread per hectare is often limited, due to Nitrates Regulations, the increased availability is a value that is of benefit to the farmers. In some of the case studies, this value cannot be realized, as crops are sufficiently supplied with nitrogen, or the digested manure cannot be used for fertiliser purposes. In some of the cases considerable amounts of surplus manure must be redistributed according to the national regulations. In such cases it is assumed that the CAD plant takes care of this, so the farmers benefit from not having to bear the transportation costs themselves. The farmers, who are assumed to receive the surplus manure, benefit from the increased fertiliser value, which is estimated in chapter 7. These estimates are also included as externalities in the socio-economic assessments in chapter 10.

Table 9.7. Economic benefits for farmers (manure suppliers) in national 2005 prices

Farmers cost savings, 1000 EUR per year	F	IRL	SP	GR	B	NL
Manure storage	-7	-14	0	0	-7	0
Manure spreading	-1	-22	0	0	-11	16
Improved fertiliser value*	16	40	0	0	17	0
Long distance transport surplus manure	0	0	0	0	22	1054
Total cost savings, 1000 EUR per year	8	4	0	0	21	1070

*Achieved by farmers in the local area. Potential fertiliser value for crop producing farmers in other regions is not included in this table

Table 9.7 presents the assessed economic benefits for farmers in each participating country. From this table it would appear that the benefits, for the farmers in the six countries, vary significantly, as a result in the differences in the basic situation. Dutch farmers may save costs in manure spreading, and save a lot of money if the CAD plant can take care of the long distance transport of the surplus manure. Belgian, French and Irish farmers are likely to have small disadvantages in manure storage, which is due to the switch in storage systems and a need to build storage for the digested manure.

The cost of manure spreading rises, in most cases, due to the increased volume from the organic waste supplied to the plant. However in these cases the farmers will benefit from improved fertiliser value. Dutch, Belgian, French and Irish farmers therefore, according to the assessed results, are likely to benefit from the system. However the amount of this benefit varies significantly, between case studies. In the Spanish and Greek case it is assumed that farmer's behavior in manure handling and application will not change even if a CAD is operating, therefore the surplus manure is not likely to be used. That leaves a considerable unutilised fertiliser value potential which could bring significant benefit if the surplus is transferred to crop producers elsewhere.

Transportation costs

Liquid and solid manure is transported by trucks from the farms to the plants. It is assumed that when a truck goes to a farm to collect slurry it will deliver digested manure. Transportation costs are taken to be paid by the CAD plant. Table 9.8 shows calculated transportation costs. In this case trucks with a capacity of 20-40 tonnes are used, depending on the application. Trucks can be owned by the plant or hired from external suppliers. It is assumed in the analysis that all haulage is hired from external suppliers.

Table 9.8. Transportation costs

	F	IRL	SP	GR	B	NL
Per day treatment capacity, tonnes	120	144	460	93	200	600
Average distance from farm to plant, km	*10*	*4*	*18*	*15*	*15,7*	*20*
Liquid manure in 1000 EUR/year	67	79	529	40	112	433
Solid manure in 1000 EUR/year	18	9	66	5	19	57
Distance for long distance transport, km	*50*	*10/50*	-	-	*50*	*100*
Long distance transport in 1000 EUR/year	48	23	0	0	78	1050
Transport costs in total in 1000 EUR/year	133	111	595	45	209	1540

The average transport distance between the farms and the CAD for the different case studies, range from 4-20 km, and up to 100 km for long distance transportation. Transportation costs are dependant on the amount of manure transported to and from the plants. In cases where large amounts of digested manure need to be exported over long distance transportation, accounts for a major cost.

Investment costs

Investments in CAD plants and combined heat and power production facilities have been assessed according to the necessary treatment capacity and the assessed methane production. Main figures are presented in Table 9.9, and further cost break down tables can be found in the national reports.

Table 9.9. Investment costs, main figures, 1000 EUR, 2005 national price level

	F	IRL	SP	GR	B	NL
Per day treatment capacity, tones	120	144	460	93	200	600
Biogas plant 1000 EUR	4217	3747	5317	2678	3900	6130
CHP facility 1000 EUR	565	395	1256	286	500	2112
Total investment costs 1000 EUR	4782	4142	6573	2964	4400	8242

The models tend to show a considerable economy of scale as far as investment and operating costs in the CAD plant are concerned. However the case studies are not directly comparable, due to national prices and differences in technology included. The French case includes a 13 km biogas pipeline which adds a significant cost and the Irish case includes a decanter separator which the other systems do not have. The Dutch case looks relatively cheap. Being the largest model plant, it benefits largely from economy of scale, and there are no pre-storage facilities for organic waste as only manure is assumed supplied to this plant.

It should be noted that although there are economies of scale to be gained with the capital costs of a CAD plant this is not the case with transportation costs, as transport distances will normally increase when treatment capacity is increased.

Profitability of the biogas plants

The basic preconditions are very important for the profitability of the plant. Considerable differences are found in preconditions identified in Table 9.10 for the different case studies

Table 9.10. Important preconditions, national price level

	F	IRL	SP	GR	B	NL
Electricity price, EUR per kWh	0,135	0,07	0,069	0,073	0,11	0,06
Heat price, EUR per Mwh	25	20	0	0	30	0
Treatment fees, EUR/ tonne	30	12,5	27	120	4,8	0*

*no organic waste processed

Obtainable electricity prices vary from 6 cents to 13.5 cents per unit of electricity. In France and Belgium, a special bonus is given to green electricity production. In some of the case studies there is no available market for the surplus heat. In the other cases considerable variation is found in heat prices. Also large variations in treatment fees are found. In the Greek case they are able to realize large income from treatment fees. These variations cause significant differences in the profitability of the plants as shown in Table 9.11.

Table 9.11. Sales and costs of the CAD plant, average national 2005 prices, 1000 EUR. Transport costs are not included

1000 EUR	F	IRL	SP	GR	B	NL
Per day treatment capacity, tonnes	120	144	460	93	200	600
Electricity sales	780	275	1083	264	600	1372
Heat sales	185	92	0	0	87	0
Treatment fees	179	230	102	273	78	0
Sales in total	1144	597	1185	537	765	1372
Costs in total	-658	-650	-988	-408	-677	-1396
Net result of the plant	486	-53	197	129	88	-24

From Table 9.11 it appears that four plants are found to be profitable, and two are found not to be profitable. Despite variations in electricity price and heat marketing, clearly the Dutch and Irish cases, where waste application is heavily restricted, have difficulties in reaching profitability. Most optimal preconditions are found in the French case where a reasonable electricity price, sufficient organic waste supplies and a market for the heat production, is found. The assessed net result of this plant is almost a ½ mil EUR on a yearly basis. Apart from poor electricity prices the Dutch, Spanish and Greek cases suffer from lack of heat marketing options. However the net profit of the plant does not tell the full story. Transportation and other costs have to be taken into account as well.

Table 9.12 shows the performance of the plant when transport and other costs are taken into account

Table 9.12. Economic performance of the plant, all costs included

1000 EUR	F	IRL	SP	GR	B	NL
Per day treatment capacity, tonnes	120	144	460	93	200	600
Transportation costs	-133	-111	-595	-45	-209	-1540
Storage of digested waste	-7	-22	-1	-0,1	-19	0
Separation of digested manure	0	-40	0	0	0	0
Net result of the biogas plant	486	-53	197	129	88	-24
Profit	346	-226	-399	84	-140	-1564
Profit if production was increased by 10%	435	-196	-304	64	-90	-884
Profit if production was decreased by 10%	253	-256	-489	104	-190	-2578

Only two plants are profitable when transportation costs are taken into account, namely the French and the Greek cases. As figures show results are robust towards a decrease in production of 10 %. For the mentioned reasons, the other four cases do not perform sufficiently well economically. However, farmers' benefits should also be considered. But even considering the farmers' benefits, as they appear in Table 9.7, the balance of the economy of the four non-profitable plants, is still unprofitable.

Socio-economic analysis

A socio-economic analysis looks at the CAD system from the point of view of the society at large. Therefore all consequences of the system in any sector of society should in theory be taken into account, - including externalities.

Externalities

Conventional economic analysis and corporate investment analysis of projects do not take the so-called externalities into account (Lesourne, 1975). Externalities, or the external effects, are expenses or income which are not directly realised by the corporate or private investor. A project may inflict burdens or contribute gains for the society relative to the reference activity, which must be taken into account when evaluating a project from the point of view of the society. A socio-economic analysis looks at the project or activity in question including externalities.

Biogas projects have implications not only for the agricultural sector, but also for the industrial and energy sectors. For the environment, mitigation of GHG emissions and eutrophication of ground water etc. are important external effects. In this study, efforts have been put into the quantification and monetisation of some of the CAD system externalities, where there is reliable data available to make the analyses.

Objectives and analytical approach

The objective of the analysis is to estimate the socio-economic feasibility of best practice CAD technology via the assessment of a hypothetical centralised co-digestion project in each of the case studies. Furthermore, the objective has been to estimate consequences for the GHG emission and to estimate GHG emission reduction costs associated with using this CAD technology.

The socio-economic evaluation compares the alternatives, where there is a CAD system, relative to its reference, no CAD or ‘business as usual’. This evaluation involves quantification and monetising of impacts of the alternative for a number of activities, - in theory in all sectors affected by the CAD system.

This socio-economic analysis is carried out at different levels, each new level taking into account still more of the external effects related to the CAD system. Four levels are included in the analysis, termed Result 0, 1, 2 and 3, where the base level (R0) does not include any externalities and the analysis at the highest level (R3) includes all effects of the lower levels, as illustrated in Table 9.13.

The socio-economic levels of analysis are characterised by:

- **Result 0**: Energy production (e.g. biogas, heat and electricity) from biogas plants. Externalities not included.
- **Result 1**: Benefits for agriculture and industry are added to the analysis.
- **Result 2**: Environmental externalities concerning GHG emission (CO_2, CH_4, N_2O) is added, if quantified.
- **Result 3**: A monetised value of reduction in obnoxious smells is furthermore added.

Table 9.13 lists a number of aspects relevant for the extended socio-economic analysis. All such aspects should in theory be quantified and monetised for the analysis.

Table 9.13. Socio-economic aspects included in the different levels of the analysis

Level of analysis: / Aspects included:	**Result 0**	**Result 1**	**Result 2**	**Result 3**
Energy and resources:				
Value of energy production (biogas, electricity)	R0	R0	R0	R0
Capacity savings related to the natural gas grid	R0	R0	R0	R0
Security of energy supplies and political stability issues				(R3)
Resource savings (energy and nutrients)				
Global balance of trades				
Increased road/infrastructure costs				
..				
Environment				
Value of GHG reduction (CO_2, CH_4 and N_2O)			R2	R2
Other emissions (SO_2, NO_x,..)				
Savings related to organic waste treatment and recycling		R1	R1	R1
Value of reduced N-eutrophication of ground water:			R2*	R2*
Value of reduced obnoxious smells				R3
..				
Agriculture				
Storage, handling and distribution of liquid manure:		R1	R1	R1
Flexibility gains at farms				
Value of improved manurial value (NPK)		R1	R1	R1
Veterinary aspects				
..				
Investments and O&M-costs:				
Investments. Biogas Plant	R0	R0	R0	R0
O&M of Biogas Plant , incl. CHP unit for process heat	R0	R0	R0	R0
Investments and O&M for liquid manure transport	R0	R0	R0	R0
..				
Other aspects				
Employment effects				
Working environment aspects, helth and comfort				
..				

* Data for the Danish case is used.

Only aspects in Table 9.13 that have been marked with an 'R', are taken into account in the present case study. All the remaining issues have not been quantified and monetised for the analysis due to lack of data relevant for the present case. The list shown in Table 9.13 does of course not exhaust the list of consequences and externalities that in principle ought to be taken into account when a project scheme should be evaluated from the point of view of society at large. This is because the patterns of consequences 'upstream and downstream' of an activity are very difficult to access, and many issues therefore are often not taken thoroughly into account in conventional analyses.

General socio-economic assumptions

The socio-economic analysis is based on a number of assumptions, for example energy price forecasts 2005-2025, which are based on the International Energy Agency`s (IEA) price assumptions from 2004, world Energy Outlook, October 2004, and Danish Energy Agency 2005 and 2006. Details about energy price forecasts are found in national reports.

All prices in the socio-economic analysis are expressed as so-called factor-prices that do not include taxes, subsidies etc. A socio-economic rate of calculation of 6 % p.a. (real, inflation not included) is used, the base year is 2005 and the analysis covers the plant operation period 2006-2025.

Identical reinvestments are included when the technical lifetime of an investment reach below 2025. Termination values of investments or reinvestments with lifetimes going beyond the time horizon 2025 are determined via annuity calculation.

Estimated socio-economic results for the six case studies

The estimates have been made for CAD plant of a treatment capacity of 93-600 tonnes of biomass per day.

CAD energy production

The CAD plant is combined with a CHP-plant (Combined Heat and Power) that utilises all the biogas produced. Energy output from the facility is electricity and heat in the amounts and with a calculated socio-economic value as shown in Table 9.14.

Table 9.14. Energy production and related socio-economic values

1000 EUR	F	IRL	SP	GR	B	NL
Per day treatment capacity, tonnes	**120**	**144**	**460**	**93**	**200**	**600**
Net heat production sold, MWh/y	7513	4671	0	0	2948	0
Net heat production sold, mil EUR/y	0,188	0,093	0	0	0,088	0
Net electricity production sold, MWh/y	5584	4003	14089	3688	5028	23068
Net electricity production sold, mil EUR/y	0,190	0,136	0,479	0,126	0,576*	0,785

* Green certificates included – see Belgian national report for further explanation

The assumed socio-economic sales prices for electricity covering the period 2006-2025 are based on the forecasted Nordpool price minus the assumed CO_2-price element (34 EUR/MWh, 2005 level). The price of heat has been assumed constant (in fixed 2005-prices) at the socio-economic price of 25 EUR/MWh.

It appears that three plants are unable to sell their heat production. The best preconditions in this respect are found in the French case study. Value of electricity production is of major importance, note that green certificates are included in the Belgian case study.

The substituted CO_2 related to electricity and heat sales is taken into account explicitly as shown in Table 9.15 below.

GHG emission reduction

Table 9.15 gives an overview of the expected overall GHG balance for the six case studies. The relevant GHG gases, CO_2, CH_4, and N_2O, differ with respect to their global warming potential (GWP); for a time horizon of 100 years, the GWP of CH_4 is 21[2] times higher than that of CO_2 (on a weight basis), whereas the GWP of N_2O is 310 times higher than that of CO_2 (Houghton et al., 1996). In the GHG emission overview, CH_4 and N_2O emissions are expressed in units of

[2] According to reference: CLIMATE CHANGE 1995, The science of climate change; Contribution of the Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change; Houghton et al.; Cambridge University Press; ISBN 0 521 56436 0. Published 1996.
The report has been approved by the COP, which is not the case for the later issue 'CLIMATE CHANGE 2001'.

CO_2 equivalents. Effects of the CAD system on GHG emissions derive from altered manure management, and from the substitution of fossil fuels.

Table 9.15. Estimated GHG reduction in each of the case studies

	F	IRL	SP	GR	B	NL
Per day treatment capacity, tonnes	120	144	460	93	200	600
Tonne CO_2 or CO_2 eq.						
Electricity sales	3575	1856	10823	2320	1762	15386
Heat sales	2637	1217	0	0	920	0
NPK substitution	622	299	1909	453	742	3932
Transport fuel	-99	-32	-454	-44	-201	-531
Total from energy substitution	6735	3340	12278	2729	3223	18787
CH_4, tonne CO_2 eq						
Animal manure	336	6	2163	840	219	7308
Organic waste	630	183	105	1848	122	0
CHP plant, unburnt	-378	-273	-1134	-252	-226	-1575
Total from reduced CH4 emissions	582	-78	1124	2436	115	5726
N_2O, tonne CO_2 eq.						
Manure and waste	839	446	6365	465	507	6737
Total reduction in tonnes CO_2 eq.	8155	3709	19767	5630	3845	31250
CO_2 reduction, tonne CO_2 eq/tonne biomass	0,186	0,071	0,118	0,166	0,051	0,142

Considerable differences are found in estimates for GHG reduction among the plants.
Firstly this is due to difference in energy production. From Table 9.4 it was learned that Belgium and Ireland obtain relatively low methane production due to the amount, type and quality of waste supplied. Thus waste supplies are not only important for economic performance, but also for GHG emission reduction, and thereby also for the socio-economic performance.
Secondly most GHG emission reduction is found when manure systems in reference are also mainly liquid systems. This is because when solid manure and deep litter is liquefied in the biogas plant, there can be more CH_4 emissions compared to traditional storage of solid manures, depending on the storage methods. For these reasons estimated GHG reduction is lower in the Belgian and Irish cases, even if they have reductions due to heat sales, which other cases do not have.

Additional comments to individual elements in Table 9.15:

- CO_2-emission reduction due to electricity sales is calculated based on the assumption that biogas substitutes natural gas.
- Heat sales are assumed to substitute heat based on fuel oil from heat boiler with a thermal efficiency of 90%.
- For the CO_2 reduction due to NPK substitution the following upstream specific energy and CO_2 contents have been assumed: (38MJ/kg pure N) 9.36kgCO_2/kg pure N, (17MJ/kg pure P) 2.67kgCO_2/kg pure P, and (6MJ/kg pure K) 0.80kgCO_2/kg pure K (Data from Refsgaard et al 1997). Data from Søren Kolind Hvid et al, 2004, have been used as basis for the CO_2eq. emission calculation.
- Increased transport fuel (diesel) consumption in the biogas-alternative means an increased emission of CO_2.
- Methane emission reductions are achieved at farms associated with the CAD plant were estimated in chapter 7 and included in Table 9.15
- Methane emission consequences related to the treatment of industrial organic waste were estimated in chapter 7 and included in Table 9.15

- Un-burnt CH_4 in the exhaust gas from the CHP-motor system has been assumed to be 1% of the methane used in the motor. This emission element specific for the combustion technology applied, is included, but technology capable of reducing or completely eliminate the emission of un-burnt CH_4 exists.
- Consequences on the N_2O emission are quantified based on general assumptions. It should be emphasized, however, that this estimation is very uncertain due to lack of detailed data for the actual situation. The general assumptions made in the present analysis are described in chapter 6.

Via converting the GHG emission to units of CO_2 equivalent emission it is seen from the table that the annual GHG emission reduction due to the introduction of CAD is calculated to be between 4000 and 31,000 tonnes CO_2 eq. per year depending on the different case studies. Seen relative to the annual amount of biomass treated in the CAD-plant this GHG emission reduction is from 60 to 190 kg CO_2 eq. per tonne of biomass supplied to the plant.

The present analysis indicates that the direct CO_2 reduction (by replacement of fossil fuel) only contributes of about half of the GHG emission reductions achieved. This is not surprising and is in line with previous studies. Previous studies (Nielsen L.H. et al, 2002) have shown that GHG emission reductions achieved due to CAD utilisation in Danish cases are almost evenly distributed on CO_2 and CH_4 reductions. N_2O emission reductions contribute about 10% of the overall CO_2-eq reduction. The overall specific CO_2-reduction seen in the Danish studies is about 90kg CO_2-equivalent per tonne of biomass supplied to the CAD plants analysed.

Annual costs and benefits

An overview of the annual costs and benefits entering the socio-economic calculation is given in Table 9.16. As previously described, the analysis has been carried out in 4 levels. But the socio-economic results are represented by Result 3, as shown explicitly in the Table 9.16. All quantified and monetised consequences available for the present analysis are included in the overall socio-economic result termed Result 3. Other levels of the analysis are found in national reports.

Table 9.16 Annual socio-economic costs and benefits for the CAD alternative, levelised annuities using Result 3, where all quantified and monetised externalities taken into account

1.000,000 EUR	F	IRL	SP	GR	B	NL
Per day treatment capacity, tonnes	120	144	460	93	200	600
Methane yields, m^3 CH_4/tonne biomass	37	21	26	30	20	29
Costs						
Investments:						
-Biogas plant	0,389	0,388	0,493	0,249	0,359	0,574
-CHP plant	0,049	0,038	0,109	0,025	0,044	0,185
Operation and maintenance						
-Biogas production	0,284	0,285	0,413	0,180	0,278	0,566
-Vehicle fuel	0,013	0,004	0,061	0,006	0,027	0,071
-Transport costs (excl. fuel)	0,104	0,137	0,456	0,036	0,132	1,374
Sum	0,839	0,852	1,532	0,496	0,840	2,770
Benefits						
Energy production						
-Electricity sales	0,190	0,136	0,479	0,126	0,355	0,785
-Heat sales	0,188	0,093	0	0	0,088	0
Agriculture						
-Storage and handling of manure	-0,014	-0,036	0	0	-0,025	-0,037
-Improved fertiliser value (NPK)	0,016	0,021	0,160	0,076	0,087	0,308

-Transport savings at farms	0,0003	-0,027	0	0,004	-0,006	1,066
-Veterinary aspects (not quantified)						
Industry						
-Savings in organic waste treatment	0,182	0,235	0,104	0,278	0,062	0
Environment						
-Value of green house gas reduction	0,165	0,096	0,399	0,114	0,078	0,631
-Value of reduced nitrogen losses	0,051	0,038	0,166	0,037	0,061	0,347
-Value of reduced obnoxious odours	0,017	0,017	0,083	0,008	0,026	0,108
Sum	0,795	0,573	1,391	0,643	0,726	3,208
Socio-economic profit	-0,044	-0,279	-0,140	0,147	-0,114	0,438

The annual costs (levelised annuity) for investments, reinvestments, and operation and maintenance of the CAD and CHP facility has been calculated using a socio-economic interest rate of 6.0% p.a..

It appears from the Table 9.16 that two of the cases are found to be socio-economically profitable given the actual preconditions. The profitability is affected by a number of parameters, which may point in different directions indicating that preconditions are inoptimal. The Dutch case is found to be the most socio-economically feasible case. In this case, it is a very large plant, which has manures with a very high dry matter content, which gives a relatively high energy production even with no waste supplied. There is also a large potential for increasing fetiliser values, and cost savings for farmers. Results would improve further if heat were utilised. Second most profitable is the Greek case which benefits mainly from processing plenty of waste. The French case is close to the break even point. It has in general good preconditions but is relatively small. The Spanish case turns out socio–economically not profitable, and so does the Belgian. The lowest profitability is found in the Irish case, mainly because direct income and energy production is low due to the restrictions on waste supplies.

The annual income elements for society or the benefits achieved are composed of benefits achieved in different sectors of society. In Table 9.16 these are grouped into net environmental benefits, benefits in industry, and in agricultural, and (net) energy production benefits.

Comments to benefits listed in Table 9.16:

- Energy: The basic assumptions on energy prices were mentioned in previous sections.
- Agriculture:
  - Transport cost elements are both positive and negative.
  - A socio-economic value of the achieved reduction in obnoxious smells from fields due to degassing manure in CAD-plants has been included. The monetisation is based on the cost difference (of 0.5 EUR/ tonne liquid manure) between soil injection of liquid manure and direct application on soil. The argument for such monetisation is, that the degassed manure has reduced obnoxious smells equivalent to soil injected liquid manure in the reference situation.
  - Data on veterinary aspects have not been available for the analysis.
- Industry: The treatment fee for organic waste supplied to the CAD plant is assumed to be that provided by the national partner.
- A quantification and monetisation for reduction in N-leakage to ground water have been assumed based on Danish general assumptions as shown in Table 9.17.

Table 9.17 Reduced N-leakage to ground water

	F	IRL	SP	GR	B	NL
Per day treatment capacity, tones	120	144	460	93	200	600
Reduced leakage, tonnes N per year	15,3	11,1	49,4	11,2	18,2	103,3
Monetised value of reduced leakage EUR/y	51500	38000	166000	37611	61000	347000

Reduced leakage: 25 % of saved chemical N fertiliser: (ref. Brian Jacobsen)
Monetised value 3.36 EUR/kg N reduced leakage (ref. Ruth Grant)

It is emphasized that considerable uncertainty is associated with these assumptions and these may not fully apply in each case.

Again, it is emphasized, that a number of important issues for the socio-economic evaluation of the scheme have not been quantified for the present analysis, as mentioned in Table 9.13.

Socio-economic electricity production costs

The socio-economic results expressed via the key-number, electricity production cost (for project break-even), are shown in Table 9.18.
To achieve socio-economic break-even for the CAD system the price for electricity generated at the facility and fed into the local electricity grid should be as shown in Table 9.18.

Table 9.18 Electricity production costs, or Break-Even electricity price for the CAD system. Estimates are based on Result 3, where all externalities are taken into account

	F	IRL	SP	GR	B	NL
Per day treatment capacity, tonnes	120	144	460	93	200	600
Electricity production costs, EUR/kWh	0,042	0,104	0,044	-0,006	0,071	0,015

Given the (levellised) average sales price at the Nordpool market assumed is 0.034 EUR/kWh covering the period 2006-2025, break even prices must match this figure if the technology should be attractive to society from an electricity point of view. The Netherlands, Belgium and Greece are below this figure, France and Spain a little above, and Ireland significantly above this level.

GHG emission reduction costs

The socio-economic results can likewise be expressed via the key-number, GHG-reduction cost achieved via the CAD system (for project break-even). For this analysis, of course, income elements from the GHG reduction achieved must not enter the calculation. On this basis the key number can be calculated **given the pre-conditions for each case study** as shown in Table 9.19.

Table 9.19 GHG reduction costs EUR/tonne CO_2. Estimates are based on Result 3, where all externalities are taken into account

	F	IRL	SP	GR	B	NL
Per day treatment capacity, tonnes	120	144	460	93	200	600
Green house gas reduction costs, EUR/tonne CO_2	26	79	27	-6	50	6

As mentioned earlier the market price of CO_2 allowances throughout the period 2006-2025 is 20 EUR/tonne CO_2. Thus the break even GHG reduction cost must in each case be lower than 20 EUR/tonne CO_2. This is found to be the case in the Dutch and Greek cases, and the French and Spanish cases are not much higher. However, it should be emphasized that this level of cost efficiency is achieved even though the CAD systems are not given optimal conditions due to existing barriers in each of the countries. If additional waste was supplied and heat could be utilised, cost efficiency would further improve.

Socio-economic conclusions

Two out of six cases were found to be socio-economically profitable when all quantified externalities are taken into account, and given the pre-conditions specific to that case study. Another three plants are close to zero, and would certainly be profitable if they were given more favourable conditions i.e. if some of the existing barriers were removed. In general the amount and type of organic waste treated and the availability of heat markets, contribute significantly to socio- economic benefits, and several cases would benefit greatly from additional waste input.

Some environmental benefits are based on Danish data due to the lack of specific data input from each national case. Therefore some of these estimates are relatively uncertain.

Summing up the results

Estimates for centralised anaerobic digestion plants have been carried out in six European countries.

Preconditions have turned out to be very variable among the case studies due to different agricultural structures, regulations, climate and agricultural practice tradition. Consequently, highly variable results have been found when case studies are compared.

Differences in amount and quality of manure and organic waste available and allowed to supply to the plants were found. Based on data input from national partners treatment capacities of the model plants were estimated to 100-600 tonnes per day, including variable amounts of organic waste. For these reasons methane yields have been found highly variable, ranging from 20 to 37 m^3 CH_4 per tonne input.

Also relatively large differences in green house gas reduction have been found. This is of course linked to differences in energy production, but also the reference systems of manure handling and utilisation are important. For example storage time of untreated liquid manure in Mediterranean areas lead to high methane losses which can be recovered if the manure is swiftly treated in the biogas plant instead. On the other hand if traditionally treated solid manure or deep litter is digested, GHG emissions tend to increase somewhat due to the liquid post-storage.

In general farmers would benefit from associating with a CAD plant. In some cases they would have slightly higher costs in manure storage and spreading due to the admixture of waste and longer storage times, but benefit from cost savings in transport and fertiliser purchase. Differences have been found in farmers benefits, that highly depends on how restricted the handling and utilisation of manure is in the reference situation. In some cases, especially the Dutch farmers face considerable costs for manure transport in the reference situation. If the CAD plant takes care of that, they obviously save a lot of money. In other cases only little surplus is found. In the Irish case farmers already utilize nutrients from organic waste, so they only benefit little from improved fertiliser value.

Two of the model plants were found to be profitable by actual preconditions. The remaining four plants suffer from lack of heat marketing, low electricity prices and/or insufficient waste amount and quality. These parameters were generally identified as important non technical barriers. In addition, in many cases, information is needed to overcome skepticism generally in the public, but also in local or governmental authorities and administration. If the barriers were removed as a part of CAD promotion schemes, all the analysed cases are likely to become profitable.

Socio-economically two cases turned out to be profitable, and three are close to the break even point. Nevertheless GHG reductions are eventually cost effectively achieved, at the socio-economic costs from -6 to 79 EUR/tonne CO_2 eq. Socio-economic profitability would increase if the mentioned barriers were removed. Actually, all the analysed case studies are likely to be socio-economically feasible if they were given optimal conditions. Especially additional waste application would boost the profitability, but also utilisation of the heat is very important from a socio- economic point of view.

Potential, barriers and recommendations

As previously mentioned the potential of the hypothetical plants in the case studies are limited by the existing barriers in each country. However, it is difficult to know when conditions are optimal. Additional waste could always be supplied which would further improve economic performance and increase GHG reduction and thus improve cost efficiency. Energy conversion might be optimised, energy prices increased or transport distances minimized. One of the case studies, the French case, does seem to have sufficiently favourable preconditions in many ways, to an extent to which it is likely to be economically feasible. Especially three important parameters should be accentuated. Firstly, sufficient waste can be supplied in order to reach a level for energy production, at which the plant is economically feasible. A methane yield of 37 m^3 CH_4 per tonne input is relatively high even compared to existing Danish plants. Secondly, a relatively favourable electricity sales price is achieved. Thirdly, heat production is sold for industrial purposes, which is very important as nearly 50% of the energy production is available in the form of heat. Given these preconditions, the main findings from the French case study are:

- The CAD system is profitable even when transport costs are included
- It is very close to socio-economic break even
- Farmers benefit economically
- Reduced Nitrate leakage of 15 tonnes N per year
- GHG reduction of 186 kg CO_2 eq. per tonne input
- Cost efficiency of GHG reduction of 26 EUR per tonne CO_2 eq.

Only one parameter that is in disfavour of the French case is the relatively small size of the plant. By additional treatment capacity per unit treatment costs are reduced and economic performance further improved. On the other hand the system must be optimized according to the possibilities to sell heat, procure organic waste and transport distances.

Repeatingly it has been emphasized that organic waste supplies are crucial to economic and socio-economic performance of the CAD system. Figure 9.5 explains why.

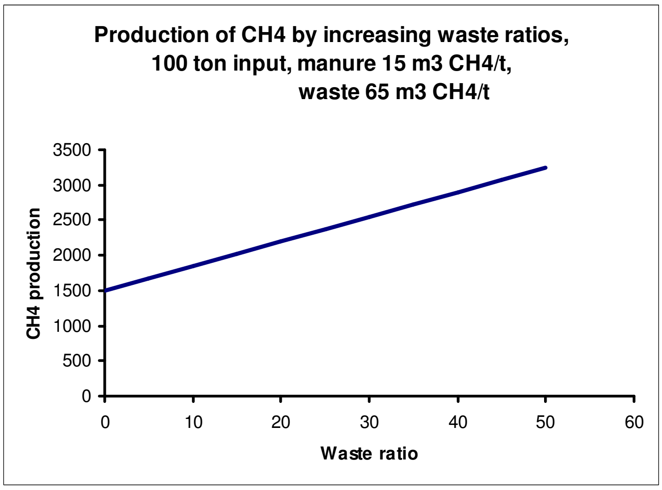


Figure 9.5. Methane production at different waste ratios

The figure is an example of digestion of 100 tonnes input, starting only with manure, and then gradually supplying more organic waste. If methane yield from manure is assumed 15 m^3 CH_4 per tonne, which is typical for the Danish situation, and from organic waste 50, methane production will appear as showed in Figure 9.7. It shows that a 50 % waste ratio wou1d more than double methane production, and consequently potential energy sales would double if heat can be utilised. Obviously, waste supplies represent a wide range of business opportunities, if sufficient amounts can be procured.

But also with respect to environmental issues waste supplies and thereby methane production is important. In chapter 9 it was concluded that GHG emission from the substitution of fossil fuels account for approx 50% of total GHG reduction from the operation of the CAD system. If the substitution of fossil fuels are doubled by a doubled methane production total GHG reductions are thus increased by approx 50 %. And consequently, GHG reduction costs would be reduced by 1/3.

In the national reports, most important non technical barriers have been identified, and recommendations for their removal are given. Some of the most important barriers are commonly present in several of the countries. Most important barriers were found to be poor electricity prices, no heat marketing options, restrictions on waste supplies and difficult administrative procedures.

The importance of the barriers is illustrated in Table 9.20. This table attempts to explain the net result of the biogas plant by showing to what extent each case has optimal conditions. In the evaluation Danish preconditions are inserted.

Optimal condition	++
Good conditions	+
Poor conditions	-

Table 9.20. Evaluation of key preconditions

	DK	F	IRL	SP	GR	B	NL
Electricity price	+	++	-	-	-	++	-
Heat market	++	+	+	-	-	+	-
Waste allowed, use of digestate	++	++	-	+/-	++	+	-
Administrative procedures, authorities helpful or reluctant	++	+/-	-	-	-	+/-	-
Net result biogas plant		486	-53	197	129	88	-24

It appears from the table 9.20 that Belgium and France have relatively favourable preconditions, almost as good as the Danish conditions, under which the technology developed. But The Netherlands, Ireland, Spain and Greece face poor preconditions in several respects. The possibility of using organic waste seems to be the most important parameter.

So what should be done?

Danish experience showed that establishment of CAD plants requires positive involvement from a range of individuals, organisations, companies, local and national authorities and the political system. It is crucial that the political system provides a legislative framework that allows CAD projects to be realized. Except perhaps the missing heat markets, all the above mentioned most important barriers may all be removed by national initiatives in each of the participating countries. This could be done by changing regulations, introducing green electricity bonus and information of farmers, companies and authorities of the potential benefits from the society point of view that are provided by the CAD technology, as illustrated in the assessed results of the PROBIOGAS project.

Electricity prices at unattractive levels.

The obtainable electricity prices in The Netherlands, Ireland, Spain and Greece are very low, compared to Belgium and France, but also to other European countries where biogas production for electricity and heat production is developing, for example, Germany, Austria and Denmark, where 8-12 EUR cents/kWh are obtainable for co-digestion plants of the dimensions in question. In the mentioned countries an introduction of a green electricity production bonus is recommended, as it would encourage power production from biogas.

Restrictions on waste application

Especially The Netherlands and Ireland have heavy restrictions on utilizing digested manure on the fields if organic waste of animal origin is included. This is a severe disadvantage for biogas production, as CAD plants, based on Danish experience, to a large extent economically dependant on the possibility to supply organic waste. The reason for this is that production is increased, and treatment fees are obtained from food processing industries. Organic waste recycling via CAD plants are looked upon very sympathetically by both environmental and veterinary authorities in Denmark, as it is considered as an attractive way to handle manure and waste, as plants include sanitation steps and input streams are regulated by (EC) 1774/2002 and national regulations. It is recommended that regulations in this field are reconsidered in The Netherlands and Ireland.

Lack of heat markets

In The Netherlands, Spain and Greece no heat market is found in the case study. This is a serious disadvantage for the economic performance of a CAD plant. It is recommended to encourage alternative ways to market the heat energy, for industrial use or district heating. It could also be considered to utilize biogas in other energy sectors, in the Dutch case via natural gas grids, and in Ireland, Spain and Greece for vehicle fuels.

Legal administrative barriers and information

The realization of a CAD plant is very complex, and involves many individuals, companies and authorities, and will get in touch with many fields of regulation. So in countries where CAD plants are not commonly known, it is recommended to give specific information about the potential benefits from this technology to relevant authorities, institutions, business branches and the public.

In the Danish context the development was favoured by the fact that markets for the energy was provided. As mentioned, district heating is widespread in Denmark, and as heat from biogas is not energy taxed heat may be sold at attractive prices for heat consumers. Electricity market is provided by purchase obligations and a fixed subsidized electricity price

Most possible organic waste recycling was for long the established Danish policy. Landfilling of organic waste is not allowed, and waste is subject to heavy tax when incinerated. Thereby the perfect incentive structure is created to lead suitable waste streams to be recycled via CAD plants. In fact this is very important from both a business and a society point of view, and shows that where economic and environmental benefits go hand in hand renewable energy sources may succeed.

Farmers' involvement in CAD projects is important for the performance of the system. Not only do they supply the raw manure, they also receive the digested manure. It is important that they understand and accept the importance of supplying manure of high quality, which means fresh and with high dry matter content. Earlier, the motivation for Danish farmers to join CAD projects was mainly the access to manure storage tanks provided by the CAD company, as they since 1986 need a storage capacity from 6-9 months. But in recent years the motivation has increasingly been directed to the distribution of surplus manure, which is required if manure from livestock production exceeds the land needed for spreading. So, in fact Danish farmers face a legislative push to seek cost efficient solutions for their environmental problems, caused by manure from livestock production. This is also the case for farmers in some of the six case studies, but apart from the Dutch farmers, it does not seem to be in the same extent as for Danish farmers.

Most Danish CAD plants are organised as cooperatives. As cooperatives are widespread in Danish agriculture, this type of organisation seemed a natural choice for organising CAD plants in the Danish context. But it also means that farmers do not withdraw large profits from the CAD companies. Their interests are found in the externalities, the derived cost savings in manure storage, transport and spreading, again coincident economic and environmental benefits.

It was a demonstration programme launched in 1988 that accelerated the technology development and enlargement of plants in Denmark. The demonstration programme proved a good way to get started, which may also be the case in the countries participating in the PROBIOGAS project. The Danish demonstration programme provided investment grants for new plants and funding for special research tasks. The demonstration programme was supported by a monitoring programme in which the gained experience was collected, analysed and communicated to farmers, plant managers and owners, companies, authorities and the political system.

The results of the assessments are to be disseminated to the target groups and to the overall European level with the aim to raise awareness among farmers, decision and policy makers and the large public about the potential and benefits of biogas from co-digestion in the respective regions

The project is expected to have some long term effects related to the impact on the specific target groups who must act for the removal of the non technical barriers. Two categories are particularly targeted. The first one represents the farmers and farmers-organisations, benefiting from improved conditions for manure handling and utilisation, easier compliance with agricultural and environmental requirements and cost savings in fertiliser purchase. The other category is represented by decision and policy makers, who should develop support schemes and operate changes in the legal framework in order to promote the development of biogas from co-digestion on a larger scale. In conclusion, it is expected that the results of the project will clarify the incentives and the barriers for each national target group, in each participant country and will establish a platform for the initiation of new future policy initiatives for the development of biogas. It is further expected that local, regional and national policy makers will subsequently initiate necessary legal changes to remove the identified non-technical barriers and to clear the way for the development of biogas. The national target group networks, involved interactively at an early stage, will form the organisational structure necessary for initiating specific biogas projects in these regions.

10. Overview of biogas situation and comments on assessment results in the studied partner countries

Biogas in France

New incentives for biogas in FRANCE

By Christian Couturier

The take off of biogas technologies occurred in France at the end of the 90'. Like many other European countries, numbers of landfill gas engines have been set up. Anaerobic digestion for MSW is nowadays considered as a realistic option, while other alternatives as incineration are declining.

But until now, the energy prices were not sufficient to allow the realization of biogas plants in the agricultural sector.

The situation is changing since the publication of new power purchase tariff in July 2006. According to this government decree, the basic price for electricity from biogas will be 90 €/MWh for plants under 150 kWe, and 75 €/MWh for plants over 2 MWe, and linear between 150 kW and 2 MW.

The plants get a "digester bonus" of 20 €/MWh if the gas is produced from a digester and not from a landfill.

The plants get another bonus for "energy efficiency" if they use the cogenerated heat. This bonus depends of the efficiency rate : the quantity of energy (electricity and heat) really valorized divided by the quantity of heat value of the biogas. Heat used for the process (digester heating, pasteurization) is considered as valorized. This bonus is nil if the efficiency rate is under 40 %, and reaches 30 €/MWh if the rate is over 75 %. It is linear between 40 and 75 %.

That means that the purchase price for a plant of 150 kWe will be between 110 and 140 €/MWh, and between 95 and 125 €/MWh for a plant over 2 MWe.

The "efficiency bonus" is destined to improve the global energy balance. It will strongly encourage the biogas producers to search heat consumers. Biogas dedicated canalizations and district-heating schemes seems to be the best solutions.

This new tariff is certainly a fact of great importance in the biogas policy in France. Numerous projects will become cost-effective in all the domains of biogas and anaerobic digestion. The sensitivity of the operators was increasing from some years ; this tariff is a

Involvement of farmers depends on other alternatives

Due to the new power purchase tariff, there is clearly a competition between individual farm-scale and collective large-scale plants, for the farmers. A farm-scale biogas plant may generate a direct income, like in Germany. In a collective project, the role of the farmers may be limited to exchange raw slurry for digested one.

The fact that anaerobic digestion improves the value of the manure is not necessarily sufficient as a benefit for the farmers. At the contrary, a CAD project induces a change in the manure management, especially with solid manure, which is the to a great extend the main form of manure in France.

The collective approach limits the profit or income but also limits the economical risks, compared to individual projects. It may also offer a better valorization of energy : potential users are not often close to the biogas plant and it's necessary to transport biogas or heat by canalization . This is economically feasible only for large-scale project.

The benefits of CAD for farmers should be demonstrated with the first CAD plants which will be built in the coming years.

District heating should be developed
As for other renewable sources, the easier way to use heat from CHP is to provide a district heating. In France only 3 % of inhabitations are connected to a district heating and most of them are located in the big cities. District heating should be a priority of local energy policies in order to promote local biomass resources.

A future renewable heat Directive of the European Union, would be helpful for the development of district heating in France.

Dedicated biogas canalizations are a feasible option
One of the interesting ways for energy from biogas is the food–industries. They usually need electricity and heat (steam). It's the case for both the projects in Deux-Sèvres and Aveyron : the natural gas consumption varies between 2 and 15 GWh, which is the magnitude of heat production from the biogas CHP units. But, in Aveyron for example, a 12 km long biogas pipe is needed. It constitutes 20% of the total investment but seems to be profitable with the heat purchase and the electricity tariff.

The regulation concerning biogas canalizations should be renewed and adapted to biogas, and the French "Club Biogas" is actively involved in this task.

Injection into the natural gas grid is allowed but still not possible
Then, injection of biogas into the natural gas grid is perhaps the best way. This option is allowed by the gas act of 2003 and the European Directive, but in practice we are still waiting for the application decrees (in particular there are no norms for trace contaminants in the gas).

A scientific team, on the cover of the AFSSET (French agency for security, health and environment at work) is working on this topic since February 2007.

Several administrative barriers remain
There is still no norm for the solid digestate, unlike for compost from aerobic plants, and this is a barrier for the commercialization and possible sale of solid digestate. Regulation about hazard for biogas plants is not clear. Few researches have been lead, for example about the explosivity of biogas or the agronomic quality of the digestate.

The adaptation of the regulation for biogas and digestate is slowly going on, in parallel to the development of biogas projects, and R&D should be strengthened in order to help policy-makers.

Wanted: the ideal CAD operator
A CAD project affects its surrounding area in many ways: management of organic matter, use of energy, treatment of waste, job creation, environmental benefits… Farmers, municipalities, private companies, may be involved in the project; but no of them are likely to invest some millions of euros in a project where the multiple benefits will be spread between everyone. In France, 3 projects reached the stage of permitting: LES, GEOTEXIA and FERTI-NRJ. The du-

ration between the first studies and the authorization approval was 6 years in all cases, and the development costs reached hundred thousands of euros. Only corporations able to invest such amounts for such long time may support CAD projects. But they have to associate local actors. Multi-party discussions involving private investors, farmers, bankers, local authorities, municipalities, is a great experience.

The potential operators for CAD projects – and their bankers - need a readability of their investments for some years. This means that food industry sector, among other partners of a CAD project, should give some assurance for a sufficient long time.

The lack of private investors seems to be solved, due to the good profitability of CAD plants. But their new interest has to be confirmed in the time.

Conclusion
Three main keys to overcome the non-technical barriers for CAD in France may be emphasized.

The first one depends on policy-makers and regulation. Energy policy may extend the possibility of use for cogenerated heat - mainly transportation of raw biogas or injection into the natural gas grid. Specific regulations are required for different aspects, such hazard regulation or organic fertilisers use.

The second key belongs to the farmers. The conditions of their involvement in a CAD project are not yet fully clear. These conditions are closely linked to local conditions and can not be transposed from a country to another or even from a region to another : management of the digestate, fertilizing value, perception of benefits from CAD, involvement in the capital share of the CAD plant.

The third key is the private sector : CAD operators, bankers, and food industry. Equilibrium must be reached between risk, profit, and confidence. Eventually, a CAD project is a reasoned gamble for the future.

Biogas in Greece
Current situation and perspectives
By Christos Zafiris

Introduction
Biogas is being promoted in the electricity market to reduce both dependence on imports and exposure to international energy markets, as well as to reduce GHG emissions in the atmosphere. The electricity market in Greece, from 1950 to 1994, was dominated by the Public Power Corporation (PPC), which was the only company producing, transmitting and distributing electrical energy in Greece. The PPC generation system consists of the interconnected mainland system (some nearby islands are also connected there), the systems of Crete, Rhodes, and the independent systems of the remaining islands. From 1994 it was allowed to auto-producers and independent producers to generate electrical energy from renewable energy sources while from 2001 the deregulation of the electrical energy market was established.

Even though the government favours the use of natural gas in power generation, low-quality lignite domestically extracted still accounts for 30.72% of Greece's total energy needs in 2005 and contributes 55.9% to the national electricity production (Ministry of Development, 2005).

Greece successfully introduced natural gas into its energy mix in 1996. In 2005, natural gas imported from Russia and Algeria in the form of LNG was estimated to account for 6.6% of gross energy consumption and gas consumption is growing fast. It has already a good footing in power production and has replaced some oil use in the industrial sector. In 2005, natural gas contributed 12.9% to the electricity production in Greece. In the future, most growth in gas demand is expected to come in power generation and in the residential and services sectors. The current gas infrastructure is sufficient to meet demand for several years.

Renewable energy sources –wind energy, small hydro, biomass and photovoltaics- contributed 3.1% to the Greek electricity production in 2005. Biogas accounted for 3.2% of RES contribution, with an installed capacity of about 24 MW, coming from the exploitation biogas energy of landfill generated in Sanitary Landfills (SL) and biogas generated in Municipal Wastewater Treatment Plants (MWTP) in the region of Attiki.

Biogas current situation and potential resources

During the 80's a few efforts for biogas energy exploitation were attempted in Greece, the feedstock being mainly animal wastes and wastes from food processing industries. Some of the efforts were demonstration projects, which were finally abandoned because of a number of reasons, the most important being the lack of proper legislation, financial incentives and lack of public awareness. Nowadays the situation had changed and there are a number of legislative measures and financial instruments available to support biogas investments in Greece and a series of information campaigns to initiate public awareness and stakeholders' involvement in biogas.

The installed power capacity produced from biogas in 2005 was 24 MW, which corresponded to primary biogas production of 1,507.2 TJ. For 2006 the respective figures were 36.39 MW and 2,905.80 TJ. The biofuel is coming from the exploitation of biogas generated in Sanitary Landfills (SL) (2,268.84 TJ in 2006) and biogas generated in Municipal Wastewater Treatment Plants (MWTP) (636.97 TJ) mainly in the region of Attiki (Table 10.1). As noted in Table 10.1, only the large-scale anaerobic digestion (AD) plants of Psyttalia and A. Liosia produce power and heat, while the rest produce only power.

So far a number of additional requests for permits have been submitted to the Regulatory Authority for Energy (RAE) and approved for about 11 MW of additional electricity generation in the coming years. This figure is relatively low compared to the potential energy generation from SL and MWTP.

Table 10.1. Anaerobic plants in Greece

Plant	Feedstock	Amount (m^3/day)	Gas production (Nm^3/day)	Primary production of biogas (TJ/y)	Installed Capacity (MW)	Produced Electricity (MWh_e)	Produced Heat (MWh_{th})
1. MWTP of Chania	Sewage sludge	17,000	1,085	9.12	0.21	130	
2. MWTP of Heraklion	Sewage sludge	23,000	3,200	26.90	0,19	465	
3. MWTP of Volos	Sewage sludge	27,000	1,500	12.61	0,35	240	
4. MWTP of Psyttalia	Sewage sludge	760,000	70,000	588.34	7,14	28,000	40,300
5. SL of A.Liosia	Landfill gas		164,000	1,107.41	13,8	264,000	0
6. SL of A.Liosia (Expansion)	Landfill gas		112,000	756.28	9,7	190,000	84,500
7. SL of Tagarades	Landfill gas		60,000	405.15	5,0	95,600	0
TOTAL			411,785	2,905.80	36,39	578,435	124,800

Regarding the potential resources for biogas production in Greece, sheep, goats and lamps breeding represents the highest percentage of livestock but this is mainly shepherded and thus the produced manure is spread on the grazing land (Bookis, I. 1997). Currently in Greece there are about 33,000 calf-breeding farms with 723,000 breeding animal heads, 36,500 pig-breeding farms with 140,600 sows, 2,500 olive oil mills, 25 secondary olive residues treatment facilities and a considerable number of food industries.

The potential users for biogas production through AD would be focused on intensive livestock, such as medium scale livestock units (Table 10.2).

Table 10.2. Biomass potential (of the main organic wastes) in Greece

Category	Units *	Capacity *	Organic wastes (t/y)	Installed capacity (MW)
Cattle	32.875	727,040 cattle	14,540,800	278
Sows	36.593	140,645 sows	2,268,220	37
Slaughterhouses	101	77,242 t/y (Cat 2) 127,690 t/y (Cat 3)	204,932	28
Milk factories (milk processing for cheese production)	548	160,362.4 t/y goat milk 447,705.2 t/y sheep milk	425,647	7.21
TOTAL			17,439,599	350.21

* Source: Ministry of Agricultural Development and Food

According to Table 10.2 and based on a conservative scenario, about 17,400,000 tons of main organic wastes are annually produced in Greece. It is estimated that the AD of manure and organic wastes from the slaughter houses and milk factories could feed CHP plants of total installed capacity of 350MW. A mean annual electricity production equal to 1.121.389 MWh_e/y (38,5% efficiency 5% maintenance) and 1.349.000 MWh_{th}/y or 4861 TJ/y (44% efficiency) of thermal energy.

Following the previously mentioned data, eight centralised anaerobic digestion (CAD) plants, of 5-20 MW installed capacity, could be constructed in Greece, in areas of high organic waste potential that is associated with high environmental risks created from their uncontrolled disposition. An advantage noted is their close proximity (all proposed plants are in a radius of 20-25 km) that lowers the transportation costs of the organic wastes to the centralised AD plants.

Legal framework and support measures

The following legislative framework on RES, including biogas, is currently in place:

- **Law 2244/94**, regarding revisions on the electricity production code from RES, and the implementing Ministerial Decision 8295/95, which broke new ground for the promotion of RES in Greece. This law remained in force only until the end of 2000, when it was replaced by the law 2773/99 for which it still acts as reference.
- **Law 2773/99** regarding the liberalisation of the electricity market in Greece. Key features include:
  a) priority to the electricity produced from RES to cover the demand of electricity
  b) a ten year contract to the producers of electricity from RES at a price which will be 90% of the existing medium voltage tariff, at maximum, for the energy produced.
- **Development law 2601/98**, replacing 1892/90, which was the main funding tool of RES applications.
- **Law 2941/2001** regarding the simplification of procedures for establishing companies, licensing Renewable Energy Sources plants, etc.
- **Law 3017/2002** related to the ratification of the Kyoto Protocol to the Framework-convention on climate change”,

The new developments in the legislative framework are the following:

- **Law 3299/2004** on promotion of investment. Subsidies vary from 40- 55% according to region, and the type of the enterprise (in case of SMEs and specific regions they can reach up to 55%) (www.elke.gr is the official site of the Hellenic Centre for Investment). Support on capital cost (up to 40%) for biodiesel plants was included in the 3rd Community Support Framework (Energy), which ended last year. The 4th Framework is under development and respective provisions are expected to be put forth.
- The Biofuels directive 2003/30 has been adopted by the Greek government late 2005, as **law 3423/2005**. According to this, biodiesel will be the main biofuel for the Greek transport sector with bioethanol playing a less important role until 2008. The amount of biodiesel required to satisfy the indicative target of 2% (on a lower calorific basis) for the year 2006 has been estimated to be circa 80.000 tonnes while the amount to satisfy the indicative target of 5.75% for the year 2010 has been estimated to be c. 148.000 tonnes.
- The Directive 2001/77 on electricity from RES has been adopted by the Greek government in June 2005, as **Law 3468/06**. According to this, a target of 20.1% RES contribution incl. large-scale hydro on electricity production in 2010 has been set. The main scope of this new law is to simplify the permitting system for the RES investments in Greece (i.e. licensing procedures). A point of strong interest is the new electricity feed-in-tariffs system, applicable for the sales of RES-produced electricity to the grid. Electricity produced by biomass is set at 73 euro/MWh.
- Join **Ministerial Decrees** 54409/2623(27/12/2004) ruling the Emissions Trading schemes
- Specific Spatial Planning Framework and Sustainable Development for RES. According to this plan, for biomass and biogas exploitation, favorable areas are considered these located in near proximity to agricultural lands where biomass is produced, waste treatment plants, food industries, animal breading farms. Minimum distances from the nearby land uses are set. The plan is under public consultation.

The financial measures set for RES applications, including biogas are the following:

- The Operational Programme of Energy (OPE) (1994-2000) of the 2nd Community Support Framework (CSF) is the most important financing instrument for RES promotion in Greece. Currently, the funding mechanisms of the Operational Programme of Competitiveness (OPC) of the 3rd CSF, initiated in 2000-2006 by the Ministry of Development, gave a further impulse to RES projects, with a total budget of about 777.6 MEURO (public funding of about 268.4 MEURO). Biomass share was 60.7 MEURO, out of which the 31.4 MEURO were spent on biogas projects.
- A provision has been applied to give the 3% of the electricity sales in favor of the municipalities, in order to curtail any public opposition in areas with high RES potential. A significant budget has been earmarked for the upgrading of the electricity network in areas of high wind or biomass potential.

It is expected that with the forthcoming 4th CSF private investors will take advantage of the funding mechanisms and the upgrading of the network and will invest.

Risks and barriers

There are a number of key risks and barriers that can threaten investment in biogas projects and thus prevent more rapid uptake of desirable technologies. Barriers associated with investment opportunities, on a macro-economic level, were categorised according to distinct but interrelated topics and include:

- Cognitive barriers, which relate the low level of awareness and understanding of the financing schemes and risk management infrastructures
- Political barriers, associated with regulatory and policy issues (lack of gate fees, lack of regulatory price for heat)

- The small-scale of projects,
- Resource availability and supply risk, either in terms of assessing the resource or contracting the supply (reduction of gas quantity and quality due to changes in organic feedstock)
- High investment costs
- Planning opposition associated with odor problems

Biogas projects suffer significantly from resource supply risk and small scale. One issue that comes up repeatedly when seeking finance for biogas and cogeneration projects is security of supply and fuel price volatility.

Large plants owners are not properly aware of the technologies for manure treatment and potential biogas-to-energy applications, while, on the other hand, small plants cannot in general effectively combine forces with other producers to form clusters of enterprises and create viable biogas plants.

The few potential investors that are fully aware of all the benefits of biogas exploitation mentioned are discouraged to proceed to similar investment due to the high investment cost and the low public subsidy (grant). The financial return for an AD plant is insufficient to repay the investment outlay, because financial analyses do not include the socio-economic costs and environmental benefits (external costs).

Although new laws and ministerial decrees have been adopted, which improve the institutional and the legal framework for such investments, these investments are resource-limited, i.e. the “polluter pays principle” is not applied practically, which would greatly improve operational costs by imposing gate fees to polluters and help remove uncertainties for the power plant owners.
Liberalisation of the energy market, that would initiate investments, is not fully implemented in Greece and PPC still retains the leading position in power generation and supply.

Perspectives and Success conditions
A realistic scenario was produced (Ministry of Development, 2005) to assess the demand for installed power capacity from RES that is needed to reach the target of 20.1% contribution of RES in the internal electricity market. According to this scenario, the requirements in installed capacity by 2010 from biomass are 103 MW, which corresponds to 0.81 TWh and accounts for 1.19% of the RES share (Table 10.3). The scenario was based on the assumption that the share of various RES types will not vary significantly in the next four years; thus the biomass-produced electricity will derive mainly from biogas. This assumption is considered as realistic given that rapid technological evolution that would lead to significant changes in the economic viability of the various technologies is not expected.

Table 10.3. RES installation requirements to meet the 2010 target

	Requirements in installed capacity by 2010, in MW	Energy generated in 2010 in TWh	Percentage share of every renewable energy source in 2010
Wind parks	3,372	7.09	10.42
Small-scale hydro	364	1.09	1.60
Large-scale hydro	3,325	4.58	6.74
Biomass	103	0.81	1.19
Geothermal	12	0.09	0.13
Photovoltaics	18	0.02	0.03
Total	**7,193**	**13.67**	**20.10**

Referring to the success conditions, some corrective actions that may be undertaken to improve and speed up the current licensing process of RES, including biogas, are outlined below:

- Strict adherence to the deadlines set for the various RES applications which are rarely respected by the public electricity company, by the relevant departments of the Ministry of Development and the Ministry of Environment, Civil Planning and Public Works, by the regional and prefecture authorities, etc.
- Substantial reduction in the number of public- sector entities (departments, committees, agencies, etc.) required to approve environmental licensing of RES installations, so as to initiate investments.
- Detailed examination of the possibility to incorporate all RES –licensing procedures into a ‘one-stop shop’ mechanism, under the supervision of the Ministry of Development.
- Creation of national clusters consisted of representatives from SMEs, technology suppliers, specialized contractors, equipment manufactures, financing providers, policy makers (Ministries, Local Authorities) etc. that would assure constant and efficient linking between different policies – on energy, environment, etc – and marketing activities on biogas deployment. The aim of such clusters would be to determine synergies, dependencies and interactions between the involved key players for each stage of a biogas plant life cycle and find out which productive systems can be derived.
- Increase of the percentage of the public funding on the investment capital costs from the 40% that is now to 50%, mainly for the advanced bioconversion technologies.
- Improvement of the biogas market conditions (increases of demand and thus increases of the selling price of the energy products). This could be achieved through the increase of the amount of the de-taxed biofuels and the price of the biogas-produced electricity to the grid (73 euro/MWh set at present to the 150 euro/MWh).

Conclusions

Biogas currently exploited is mainly in the form of landfill gas and sewage sludge generated gas. However, Greece has a high organic waste potential that currently is not exploited. Eight CAD plants could be constructed, with a total installed capacity of 350 MW, in areas of high organic waste potential.

The legislative framework and financing mechanisms are constantly being improved, but the still high investment costs coupled with the lack of public awareness on biogas production advantages, the lack of implementation of a ‘gate-fee’, as well as the lack of socio-economic costs and environmental benefits (external costs) reflected in economic analysis of a CAD plant hinder the biogas deployment in Greece.

More information can be found at: www.dei.gr, www.elke.gr, www.minagric.gr, www.minenv.gr, www.rae.gr, www.ypan.gr

Biogas in the Netherlands

Stimulating co-digestion in the Netherlands

By Bert van Asselt

SenterNovem a governmental organisation (part of the Dutch Department of Economical Affairs) is involved in the EU-PROBIOGAS Project. In this paper a overview of the Dutch developments as a result of the PROBIOGAS Project is given.

Introduction

At the start of the PROBIOGAS project co-digestion in the Netherlands was difficult to realise. In this paper a summary of events with respect to the PROBIOGAS project concerning the development of co-digestion in the period 2005-2007 is presented.

Until 2005 digestion of manure in the Netherlands was carried out on small scale. A few farmers and farming institutes were experimenting manure digestion.

In 2004 and 2005 the climate towards co-digestion of manure was changing in the Netherlands. Until 2004, co-digestion in combination with reuse of digestate as fertiliser was not allowed. In June of that year the “positieve lijst” was presented. Agricultural products on this list could be used for co-digestion without excluding the use of the digestate as fertilezer. A financial stimulation of digestion was the subsidiary of green electricity produced from biogas. Since January 2005 for each kWh of produced electricity from digestion of manure a bonus of Euro 0.097 was given by the Dutch government. This bonus was really effective in stimulating co-digestion. During the last two years the number of co-digestion plants was increasing from less than ten in 2005 up to more than 50 at the start of 2007.

Due to this development the question can be made “is stimulation of co-digestion with respect to the Pobiogas project still necessary”.

Answering this question is not so easy because the Dutch agricultural sector varies from the north to the south. The southern can be described as a livestock intensive area. Because of these activities and the shortage of fields for reuse the manure this part has a surplus of manure. Digestion or co-digestion of manure will not solve this problem. Combination of digestion with other techniques to reduce the amount of manure could be one of the solutions for the surplus of manure in this part of the Netherlands. The Dutch involvement with the PROBIOGAS project was to deal with the problems of manure in the Dutch livestock intensive areas and to stimulate co-digestion of manure more national wide.

The Dutch case

SenterNovem has a good view on most projects concerning digestion of manure in the Netherlands. SenterNovem was involved in the BRK-project and presented this project as the Dutch case. Near the city of Eindhoven, the region “de Kempen” is an area with intensive agricultural activities (pig, cattle and poultry). It is not possible to reuse the produced manure as organic fertiliser within the area. A surplus of at least 1 million tons has to be transported to other regions. In order to reduce the costs of manure disposal, a group of farmers has founded the “Bio-Recycling de Kempen” (BRK). The BRK has plans to build and operate a plant for the treatment of manure. In the first stage of the plant, slurry of both pig and cattle manure will be mixed and separated in a thin and thick fraction. The thin fraction will be treated in an aerobic purification plant (dephosphation and denitrification). In the next stage the thick fraction will be digested in combination with poultry manure. The capacity of the plant will be about 225.000 tons of manure. Since June 2006 several farmers, which produce a total of 200.000 tons of manure, have joined the BRK.

The case has been studied by the Danish experts and their main conclusions can be summarized as followed:

<u>Non-technical barriers</u>

Three main reasons for the relatively poor economic performance can be identified as the most important barriers for an enlargement of CAD plants in The Netherlands:

- No waste application is allowed
- Relatively low electricity price
- No market for the heat.

This is in spite of the fact that the Dutch case has excellent preconditions regarding the quality of the biomass supplied to the plant, as it has very high dry matter content, which is an important parameter.

Socio-economic/cost-benefit analysis
The socio-economic analysis looks at the biogas-scheme from the point of view of the society at large. Therefore all consequences of the scheme in any sector of society should in theory be taken into account, - including externalities.

Biogas projects have implications not only for the agricultural sector, but also for the industrial and energy sectors. For the environment, mitigation of greenhouse gas (GHG) emissions and e.g. eutrophication of ground water etc. are important external effects. In this study, efforts have been put into the quantification and monetisation of some of the biogas scheme externalities. Four levels are included in the analysis where the base level does not include any externalities, and the top level includes all quantified and monetised externalities. However, it was not possible to quantify all externalities relevant for the study, such as veterinary aspects.
The socioeconomic analysis does not show the profitability from a business point of view, but it shows the profitability from the society point of view, which means that its results can be used as input and arguments in developing agricultural, energy and environmental strategies.

Socio-economic fuel prices are based on IEA (International Energy Agency) and DEA (Danish Energy Authority) forecasts of future fuel prices.
Electricity purchase is assumed at the socio-economic price that includes costs for transmission and distribution. Sale of electricity, however, is assumed to get the spot market price for electricity. (a result of the decision of the Dutch Government to stop subsiding electricity from sustainable sources).
Diesel and gasoline prices `an consumer` have been assumed.
It is assumed that heat production from the plant can not be marketed.
A quantification and monetization for reduction in N-leakage to ground water have been based on Danish general assumptions. N leakage reduction is 25 % of saved Chemical N fertiliser, monetized by the value of 3,36 €/kg N. It should be emphasized that considerable uncertainty is associated with these assumptions and these may not apply fully in the Dutch case. Specific data for the Dutch case have not been available for the present analysis.

Conclusions

The significant manure surplus situation in the Noord – Brabant region in The Netherlands form excellent preconditions for CAD plants in this region. Farmers would largely benefit economically as they may achieve considerable cost savings in transport, as the CAD plant is assumed to take over transport costs for surplus manure export to other Dutch regions. Receivers of surplus digested manure benefit from cost savings in fertiliser purchase. Relative high dry matter contents in the manure forms a large potential for biogas production However, the estimates for the economic performance of an imaginary CAD plant in the region, based on the assumptions made, shows that the system is not economically feasible by the existing preconditions. Electricity price is relatively low in a European context, lack of heat utilization options is a serious disadvantage and organic waste admixture is not allowed. These are the most important non technical barriers that should be removed if CAD plants are to enlarge in The Netherlands.
Socio-economic assessments show that CAD plants, again based on the assumptions made, are indeed attractive for society as multifunctional tools for solution of agricultural, energy and environmental problems in livestock intensive areas in The Netherlands like the Noord – Brabant region

Large Scale Digestion in the Netherlands – After PROBIOGAS

Despite of the results of the Danish analyses realisation large scale co-digestion plants in the Netherlands is still difficult and taking time. The economical feasibility has become worse because of the change in subsiding green electricity since August 2006. This means that all initiatives for co-digestion in the Netherlands are put on hold and waiting for a new system of stimulating sustainable energy (electricity-heat-green gas).
Other developments since 2005 are that due to the possibility of using waste products from agricultural origin as co-products for co-digestion the biogas production per digestion-plant has increased during the last years. The capacity of electricity production has risen from 200 kW to 1 MW per plant. Also the capacity of the digester is increasing (10.000 tons in 2005 up to 36.000 tons in 2007).
As a result of the PROBIOGAS Project SenterNovem has stimulated co-digestion in the Netherlands by means of organizing presentations, workshops, and preparing fact-sheets of (digestion) projects. In order to shorten the process of legislation SenterNovem introduced a service to bring in knowledge of members of the local government which are experienced in the legislation process of co-digestion. This service has improved the knowledge of co-digestion among the other members of local governments and speed up the process of legislation.
It can be concluded that large scale co-digestion of manure in the Netherlands is still difficult. The increase of the number of small-scale plants during the last two years has shown that co-digestion is an excepted technology in the Netherlands. In combination with manure/digestate treatment techniques for the future there will be a marked in the Netherlands.

Biogas in Spain

Barriers and incentives of centralised co-digestion in Spain. Case study of Pla d'Urgell, Catalonia

By Joan Mata-Álvarez

Introduction

Spain is the second largest pig meta producer, behind Germany in the European Union, with 3% of the world output and 16% of the EU production (Lence, 2005). According to the Catalonian government, 28% of the Spanish pig production takes place in Catalonia, where more than 10,000,000 m^3 /year of animal slurry are produced.

Pig producers in the areas with the heaviest concentration of production facilities in Catalonia are forming cooperatives to build waste-disposal plants that eventually transform slurry into electricity and fertiliser.

Main problem of pig manure is the high ammonium concentration of slurries, linked to the intensive exploitation areas, which results in a very important surplus of nitrogen in certain regions. According to Mata-Alvarez (2003), the Netherlands with 200 kgN/ha/y is heading the European mean surpluses of N. Spain has an average value of 21, but Catalonia has a large concentration of around 74 kgN/ha/y. This makes an overall excess of 30,000 t N/year, but in some areas, as Pla d'Urgell, the surplus rises to 500 kg N/ha/y, that is, more than double of the allowed value in accordance with the 91/676/CEE nitrogen directive.

These values can be used as a guideline to select the right location of centralised treatment, and in fact, Pla d'Urgell has been chosen a case study of PROBIOGAS project. Another area in Catalonia with a similar surplus of N is "Les Garrigues", where already two centralised digestion plants for pig manure exists.

AD centralised plants has a number of advantages summarized bellow.

- AD has implications not only in the agricultural sector, but also for the industrial and energy sectors:
- Stabilization of the organic matter.
- Reduction of odour emissions
- Mitigation of GHG emissions
  - electricity,
  - manure storage,
  - reduced emissions of N_2O in soils after manure spreading.
  - CO_2 reduction when no Chem. N fertilizer. is used.
  - (transport of manure increases and CH_4 can leave the CHP plant unburned)
- Mitigation of eutrophication of ground water (saved Chemical N fertilizer)

Taking into account the number of livestock units, the total amount of manure produced in these 3 farms can be estimated to be around 57200 t/y. Considering all the pig farms in the area, this amount is increased until 129500 t/y, whereas cattle manure amounts approximately 30000 t/y, poultry around 4700, and other organic waste coming from food industry, almost 4000 t/y. All these wastes and manures gives a total yearly amount of nearly 170000 t/y. Presently, these amounts of waste are either spread in due time (normally once per month, except in Winter) in the fields or sent to a composting plant (solid fraction or industry waste) where they are processed and used later in the fields. This composting process cost to industrial producers can be estimated to be around 25€ per ton.

It seems that a centralised co-digestion plant could help in reducing the cost treatment for industrial wastes, potentially increase the fertiliser value of manures and to decrease the GHG emissions due to manure storage. In addition biogas would be produced which could be transformed into electricity and heat. Unfortunately, heat could not be used for district or industrial heating, because of the distances and the climate conditions. Another added benefit of centralised co-digestion would be the reduction of odours.

Centralised co-digestion plant

The Danish expert group took basic data shown in the above section and some other concerning temperatures, seasonality, etc. and proceeded to design the centralised co-digestion plant. As the amounts of biomasses were fairly low, they consider to comprise other piggery wastes available in the region. As a summary Table 10.4, shows all the sources of biomass considered for co-digestion.

Table 10.4. Total yearly amount of biomass resources considered in the project

Type of biomass resources	Tonnes
Cattle manure	29690
Pig manure	129500
Poultry manure	4700
Organic waste	3850
Total	167740 (460 t/d)

From this biomass approx 4,4 mil m^3 methane production is estimated in two digesters of 3,500 m^3. In the CHP plant this energy is converted into electricity and heat. Electricity which may amount to approx. 16000 MWh is sold to the grid; heat can not be utilized, apart from some heat used for process heating

The plant is operated at thermophilic temperatures, which means 52-55 ºC and 15 days retention time. The plant is equipped with 70 ºC pre sanitation step, heat exchanging, biogas cleaning facilities, odour control system, storage facility for biogas and CHP plant for heat and power production.

Investment cost have been estimated to be as follows (in thousand Euros):

- CAD Biogas plant 5300
- CHP facility 1250

In the following section and analysis of costs benefits, based on several factors (Mata-Alvarez et al. 2006) is performed. A number of externalities relevant for the socio-economic analysis have not been included due to lack of data.

Annual costs and benefits

The annual costs and benefits analysis has been carried out in 4 levels termed Result 0, Result 1, Result 2, and Result 3, characterised by:

- Result 0: Energy production (e.g. biogas, heat and electricity) from biogas plants. Externalities not included.
- Result 1: Benefits for agriculture and industry are added to the analysis.
- Result 2: Environmental externalities concerning GHG emission (CO_2, CH_4, N_2O) is added, if quantified.
- Result 3: A monetised value of reduction in obnoxious smells is furthermore added.

When the sum of the monetized annual benefits exceeds the costs the proposed scheme is of-course attractive for society based on the assumptions made. From the negative net benefit Result 2 value, that the CAD scheme in question is not attractive for the society and that a socio-economic annual deficit of about 223000EUR/year could be expected. Including Result 3 assumptions and the monetized value of the externality 'reduced obnoxious smells', the estimated socio-economic deficit decreases to about 140000EUR/year. The full text of the analyse can be found in the Spanish national assessment report at www.sdu.dk/bio.

As a summary, with respect to the availability and quality of manure and waste, preconditions are relatively favourable for this case. But low electricity prices and the lack of heat marketing options form serious barriers for economic operation. Calculations show, that the biogas plant itself would be economic, but it is not able as it seems also to cover transport costs. This situation could be altered by supplying more organic waste, or finding a market for heat to improve energy efficiency and economic performance.

Conclusions

The main conclusions of the socio-economic analysis of the proposed CAD-plant project for Pla d'Urgell, Catalonia, Spain (Base Case) are:

- Based on Result 0 assumptions the plant is not attractive. Thus, the socio-economic value of energy production alone can not justify the deployment of the proposed biogas plant project.

- Based on Result 1 assumptions, where net agricultural benefits and benefits for industry concerning treatment of organic waste are included in the analysis, the proposed project remains unattractive for society at large.
- Based on Result 2 assumptions where the calculated environmental implications (net benefits) on Green House Gas emissions (CO_2, CH_4, and N_20) and N-eutrophication of ground water furthermore are taken into account, the annual socio-economic deficit is calculated as 223,000EUR/year.
- Including furthermore the estimated externalities related to reduction of obnoxious smells (Results 3), the annual socio-economic deficit is reduced to about 140,000EUR/year for the biogas plant in the configuration considered.

These results clearly show that the economy is, of course, a barrier. But what about the incentives? Social benefits are, in a way, an incentive, but, right now, from the economical point of view the only incentive for farmers is the sale of electricity. With the present situation and at the present price this is not a real incentive. As the only way of being remunerated is the electricity sales, the creation of green certificates to increase the electricity fee up to a 14-16 €/MWh . This has been pointed out in a recent meeting with TGN in Barcelona, in the framework of the PROBIOGAS project. Other incentives such as the sale of heating power or finding additional environmental benefits, are right in theory but too far from the practice for farmers. Additionally, it should be taken into account that the CAD is not going to solve the problem of the manure excess. Thus farmers should find a real profit to invest in this kind of projects. However, the estimation carried out here, shows that the feasibility is not so far, if a small help from the administration, establishing better fees for the electricity sales.

Biogas in Ireland

The potential for co-digestion in Ireland

By Vicky Heslop

There are no CAD or large scale co-digestion facilities in Ireland, although some potential projects have completed in depth feasibility studies. In 2002 a report, commissioned by the Environmental Protection Agency (EPA) identified 10 potential sites in Ireland for CAD facilities. The Irish case study, in N.Kilkenny, used for PROBIOGAS was one of the top three identified sites, in that EPA study. This site is in the north-west corner of the South East Region of Ireland. It is therefore a very central location, within the whole of Southern Ireland. The road that joins the two major cities of Ireland, Dublin and Cork, runs through the area. The area is sparsely populated, and mainly agricultural, with small (>250 people) villages.

The case study site is located near a large dairy processing facility that produces large amounts of sludge (16,000tpa) from its waste water treatment facility. There are several other food processing companies within a 60km radius, that would have suitable waste for a CAD. Under the Regional Waste Management Plan there is a need for a second food waste processing facility for the Region of up to 50,000tpa. There is also a need for a processing facility for the sludge produced by the small rural community sewage works in the county, both needs this project could have met.

The latest Agricultural statistics show that in Kilkenny county there are 1,352kt cattle, 149kt pig and 0.7kt poultry manure collected in the year. In North Kilkenny farming is mixed with dairy, tillage and pig production. Most of the cattle farms are dairying, with most of the calves being kept through to be replacements or for beef production. Nearly all farms are family owned farms whether livestock or arable. Some of the farms are in both arable and livestock production, but there are also purely arable production units.

Soils are variable, ranging from dry, free draining to waterlogged ground. Large areas of the county have gravel topsoil and limestone subsoil, and therefore are vulnerable to nutrient and pathogen contamination of groundwater. The River Nore, one of Ireland's largest rivers, and several other waterways run through the area. Most the land (unless waterlogged or the small area of upland in NE and NW) is very fertile alluvial soils and agriculture production is high. There is also quite a high level of Tuberculosis in the cattle herds in the area, which local vets believe is partly caused by untreated slurry spreading.

The Regulatory conditions in Ireland

The Irish Nitrates Regulations 2006 came into force in August 2006, and require farms to have at least 4 months storage capacity and define acceptable spreading times. The Regulations control the amount of available Nitrogen that can be applied and the amount of Phosphate for different crops and the amount of Nitrogen applied in the form of manure (170kg/ha). The draft Regulations of 2005, had indicated that the 170kg/ha limit would apply to N from all organic sources. The change that occurred between 2005-6 meant that organic waste from food processing can continue to applied to land with the only limit being crop requirements for available N and the P content and soil P status. This change has removed the driver for food processing companies that have traditionally landspread their waste to find other systems of waste management for the material.

Until December 2006 the Irish Regulations on Animal By-Products, prohibited the spreading of digested products made from feedstock that contained meat, from being spread on farmland. Even today the interpretation of the latest National legislation is still unclear, in relation to category 3 wastes, other than catering waste. The digested products, from a biogas plant licensed to process catering waste, may be spread on farmland, so long as grazing farm animals do not have access, within 3 weeks of spreading (60days for pigs).

CAP reform and the Single Farm Payment, has resulted in uncertainty of the future of farming in Ireland and has caused major changes in landuse. It has also resulted in many farmers (particularly on small farms) becoming part-time farmers or selling up.

Waste Strategy – By 1997 all regions of Ireland had developed Regional Waste Management Plans that outlined what infrastructure was required for each Region to manage its municipal waste arisings. The SE Region advised that biodegradeable waste should be treated by biological means and that 2 of 50,000tpa facilities should be built. The National target is that 33% of biodegradeable municipal waste should be treated by 2010.

Renewable Energy targets in 2005 were that 13% of electricity consumption should be generated from renewable resources by 2010, nearly all of this was expected to come from wind or existing hydro.

National Climate Change Strategy identifies agriculture as the sector with the highest emissions in Ireland and sets a reduction target of 1.2Mtpa from the National herd, 0.06Mtpa from changes in manure management and 0.9Mtpa from reduced fertiliser use. Large users of energy are required to participate in International Carbon Trading (ICT) and are issued with carbon credits by the EPA.

Waste Licensing – A facility that processes waste and that holds more than 1,000tons of waste on site at any time requires a waste licence from the EPA to operate. This licence places defines the manner of operation, the quality of end products, and places exacting reporting requirements on the facility.

Grid Connections – Ireland has a linear National Grid system that can make it difficult in many areas for the grid to accept embedded generation. Due to large volumes of wind power wishing to come on to the system, there is now a gate system operated whereby any proposed generator >500kw must apply for connection and wait till the next gate before they receive an estimate. The period between gates is an unknown. A prospective generator must also obtain a licence to build a generating station and a licence to operate.

In 2005 the Support measures that were potentially available were from Sustainable Energy Ireland (SEI) under their RD&D funding for RE. This required the project to have an element of novelty. In 2006 the Government Dept. responsible for energy introduced REFIT a feed-in support scheme for RE, whereby 7.2c/kw would be paid to the electricity supplier for any electricity they purchased from a biomass generator. And also in 2006 a competitive MOTRII scheme which awarded a small number of excise duty exemptions to biofuels projects, and biogas vehicle fuel would have been eligible. Up to 70% capital grants were available to farmers to install additional storage capacity for manure to meet the Nitrates Regulations.

The combined effect of Irish policy on the design of the case study for this project

The period 2005-8 offered a 'golden opportunity' for the development of a CAD in Ireland, because the CAD would have helped farmers meet the Nitrates Regulations without having to decrease stock numbers or output and most farmers would have qualified for 60% grants for the required farm alterations and long term digestate storage. However, as the grassland farmers, supplying slurry, wanted at least the same amount of nutrients back this meant that the CAD would not be able to process any wastes that contained meat, because of the National ABP rules.

The changes in the Nitrates Regulations between 2005 and 2006, resulted in the dairy only being willing to pay a gate fee to the CAD for taking the WWTP sludge, equivalent to the cost of landspreading the raw material (€12.50/t).

The price available for the electricity generated provided very low income to the CAD, after allowing for the cost of generating, even with the introduction of REFIT with a price support of 7.2c/kw. However, as the dairy processing factory is involved in ICT, the carbon credit value of using biogas to replace natural gas to produce heat, could provide additional revenue for the energy, if used to replace natural gas in the factory boilers. SEI offered to provide up to €1 million if this approach was taken as using biogas for heat was sufficiently novel in Ireland. However, for the case study to fit into the Danish model, it was necessary to presume the biogas would be used in a CHP, so the SEI grant was not applicable.

The uncertainty about how the Irish ABP rules regarding spreading would be reformed, made it impossible to design the case study to operate as most existing CAD facilities do.

Defining the feedstock and CAD design for the case study

Initially it was proposed that the case study should include two separate digester lines, one that would produce digested products for grassland and one that would process ABP material and plan to utilise the digested products as arable fertiliser. This was agreed in principle by the Dept. of Agriculture. It was proposed to process predominantly food waste and sewage sludge in the ABP line, along with a small amount of slurry. However the Danish model could not accommodate two different digesters in one project. Also there was no data available within the model relating to food waste or sewage sludge. So it was decided to proceed with the case study with one digester that would process 3,200tpa of FYM, 31,132tpa of slurry and 18,000tpa of sludge from the dairy WWTP. The sludge included fats collected from the Diffused Air Flotation unit.

Table 10.5 Biomass resources and predicted gas yield

Biomass	Amount Ton/year⁻	DM %	DM Kg/year⁻	VS Kg/year⁻	CH_4 yield nm^3 CH_4/year⁻	Biogas 60% CH_4 nm^3/year
Cattle slurry	31,132	7	2,148,108	1,718,486	343,697	572,828
FYM	3,240	20	648,000	518,400	77,760	129,600
Dairy WWTP sludge	18,000	14	2,440,000	1,952,000	691,200	1,152,000
Manure and waste	52,372	10	5,236,108	4,188,886	1,112,657	1,854,428

The digester design was a standard Danish design, consisting of a reception hall with a mixed tank, which fed into a holding tank before passing through heat exchangers and a pasteuriser into the digester. The digester to be operated at 55C. The digestate would be separated (by centrifuge for the model) to remove the coarse fibres (fibre) from the liquid (liquor) fraction. The liquor would then pass to a storage tank from where it is collected to be taken to the receiving farms for long term storage, until it is used. The fibre would be stored on site in a shed where it is composted to fully stabilise it, before it is transported out of the area to a compost product manufacturer.

The gas is collected from the digester and liquor store and is scrubbed before entering a buffer storage tank from where it is fed into a CHP unit to produce electricity and heat.

Operating parameters of the case study

60-70 farms would be involved with the CAD, all within a 7km radius of the CAD site. The manure required to be supplied by about 5,700LSU of cattle. The time that these cattle are housed varies from farm to farm, age and type of stock and from year to year, depending on the weather conditions. Some animals may only be housed for about 50 days, others 160 days. The manure management systems include a) scrapper systems where the slurry is removed from the houses to an outside store regularly during each day; b) slatted tanks where the slurry is stored under the animal houses and c) straw bedded houses (FYM) During winter the slurry from the scrapped systems will be collected within a week of its production and some of the stored slurry in the slatted tanks will also be required. The FYM and the slurry from slatted tanks will be collected in the summer months. Therefore the amount of manure being supplied to the CAD can remain steady all year round.

About 2,300ha of grassland is used to maintain these cattle. Some of the farms have stocking rates in excess of that permitted under the Nitrates regulations. The soil P index of the land ranges from 1-4. These livestock farms also have between them about 70ha of wheat, 185ha of barley, 80ha of sugar beet and 150ha of other arable crops. Due to changes in CAD plant and World Trade arrangements, the use of land in the area may change. However, these farms should provide a large enough landbank to utilise all the liquid products produced by the CAD, even if land use changes. The separated solids will be sold out of the area as a base for horticultural compost production.

Results of the case study

Nutrient Management of the farms in the case study

The case study assessments were made prior to the issue of 2006 Nitrates Regulations. The nutrient analysis of the feedstock and the availability of Nitrogen (taken as early Spring application) is that which was advised by Teagasc, at the time, and actual analysis of the dairy sludge. The calculations assume that no more than 170kg/ha of Total-N from organic material will be spread, and that overall the grassland a maximum of 13kg of P could be spread. In the situation where there is no CAD and wastes are spread untreated, 13,952tpa of the 18,000tpa of sludge would not be able to be used on the farms but would be exported to other farms outside the case study area. With the CAD 3,570tpa of the fibre would need to be sold out of the area.

The effect of processing all the sludge and manure in the CAD increases the Nitrogen availability, and reduces the amount of Nitrogen losses into the environment by 89tpa within the case study area and 36tpa saved outside the area. Correspondingly there would be a saving of 72tpa of Nitrogen fertiliser purchases, overall. Within the case study area there is a saving of over €40,000pa in artificial fertiliser purchases, or just over €10/ha. (assuming N/t = €710 and P/t = €1,625) because some additional P fertiliser will be required if only liquor is used on grassland. The assessment was based on the 2005 Nitrates Regulations, under the current Regulations nearly all the digested products could be utilised in the case study area, which would bring further fertiliser cost savings.

Table 10.6 Nutrient equation

	quantity tpa	dm	Total N kg/yr	NH4 kg/yr	NH4 %of total N	P kg/yr	K kg/yr	N lost Kg/yr
CAD output whole	49,753	4.7%	178,655	120,349	67.4%	39,919	207,900	
Liquor	45,276	2.2%	128,084	109,456	85.5%	11,173	189,082	18,628
Fibre used local	908	32.0%	10,252	2,208	21.5%	5,828	3,815	8,044
			Total N unaccounted for with digested products					26,672
slurry	31,132	6.9%	112,075	28,019	25.0%	18,679	133,868	84,056
manure	3,240	20.0%	14,580	1,944	13.3%	3,240	22,032	12,636
sludge spread	4,048	14.0%	22,669	3,967	17.5%	4,048		18,702
			Total N unaccounted for with untreated products					115,394
Sludge exported	13,952	14.0%	82,317	14,405	17.5%	41,856		67,911
Fibre exported	3,570		40,319	8,685		22,918	15,003	31,634
			Total N saved from being lost from exported material					36,277

The farmers will have an additional spreading cost to deduct from this fertiliser saving as an additional 13,300tpa of liquor will be spread compared to manure. The farmers would also require additional storage capacity on farm, it is assumed that the farmers obtain a 60% grant and the balance of the cost of storage is paid by the CAD.

Greenhouse Gas Emissions

The case study assessment has calculated that 71kg of CO_2 equivalent are saved per ton of biomass treated, even when the CAD is not taking wastes that would otherwise be disposed of to landfill. The CO_2 savings represent 90% of the GHG emissions avoided, whereas with most CAD, other gases make up 50% of emissions avoided. Therefore if the Irish CAD could process ABP waste the GHG emissions avoided would be much higher. The saving in emissions in the case study is calculated by considering the following

g) methane emissions from stored manure and sludge
h) Nitrous oxide emissions reduction achieved by mineralisation of the Nitrogen during the digestion process
i) The carbon dioxide emissions avoided by replacing fossil fuel (natural gas) to generate the net output of electricity and heat
j) Allowing for emissions of unburnt methane (1% of fuel) in the CHP exhaust
k) NPK fertiliser substitution
l) Changes in transportation fuel

Table 10.7 Greenhouse gas emissions

	Gas type	Gas as produced tpa	Equivalent in CO_2 tpa
Electricity sales	CO_2	-1,856	-1,856
Heat sales	CO_2	-1,217	-1,217
NPK substitution	CO_2	-299	-299
Transport fuel	CO_2	32	32
Manure storage	CH_4	0.3	6.3
Sludge storage	CH_4	-9	-189
CHP unburnt gas	CH_4	13	273
Manure/sludge/fert	N_2O	1.44	-446
			-3,709

For the CO_2 reduction due to NPK substitution the following upstream specific energy and CO_2 contents have been assumed: (38MJ/kg pure N) 9.36kgCO_2/kg pure N, (17MJ/kg pure P) 2.67kgCO_2/kg pure P, and (6MJ/kg pure K) 0.80kgCO_2/kg pure K

Financial Matters

Capital cost of the case study CAD facility in total came to €4,171,000 (Biogas plant= €3,747,000, CHP=€395,000, centrifuge=€157,000). There is some uncertainty in applying this capital cost as the smallest Danish model was twice the size, and there are significant economies of scale with a larger CAD size.

The net result of operating a CAD of this size and on manure and a sludge for which only a low gate fee can be charged (€12.50/t) results in the project having low gas yields and operating at a loss of €225,000 per year after all financing costs are allowed for.

Table 10.8 Operational costs and revenue

Revenue	,000 €	Costs	,000 €
Electricity sales (4,671 MWh)	275	Electricity purchase for process	-25
Heat sales (4,003 MWh)	92	Maintenance	-127
Sludge treatment fees	230	Sand removal	-2
Fibre (nutrient value €19,000pa)	0	Insurance	-18
		Other costs	-18
		Staff costs	-103
		Premises	-6
		Administration	-15
		Capital financing of biogas plant	-336
		Costs of biogas facility	- 650
		Capital financing storage & separation	-62
		Transportation costs	-111
Total Revenue	597	Total Outgoings	- 823

<u>Socio-economic assessment</u>

Not all the socio-economic benefits of CAD have been included in the calculations, as insufficient data is currently available. Those emitted include, security of supply, saved resources, global balance of trade, effect on infrastructure (eg roads, grid), Sox/Nox, animal and human health benefits, employment and rural development benefits.

Table 10.9 Socio-economic values

		€
Energy	Electricity sale*	136,000
	Heat sale	93,000
Agriculture	Improved manure value	40,000
	Added spreading costs on farms	- 27,000
	Transportation	111,000
Industry	Disposal cost avoided	230,000
Environment	GHG reduction	96,000
	Reduced N eutrophication of groundwater	65,000
	Reduced obnoxious smells	26,000
	Total socio-economic benefit	**548,000**

* The value of electricity sales assumes that biogas produced (net) and used for electricity pro duction substitute natural gas (by energy content). The corresponding CO_2 substitution or reduction is assigned to the electricity production part of the biogas plant output.

Conclusion

A CAD plant in Ireland will not be economically viable, unless at least one or more of the following can be achieved

- A reasonable gate fee can be charged for at least some of the waste processed
- Digested products can be spread to grassland, even if contain meat in the feedstock
- The value gained for energy generated increases
- The socio-economic benefits are rewarded
- The Nitrates Regulations are applied in a manner that reflects the Nitrogen loss avoided rather than the amount of total N applied

CAD facilities in Ireland are unlikely to be able to avail of the economies of scale achieved in other countries, because livestock farming is mostly not intensive and food processing and population is scattered. The road system in rural areas is poor and there are few sites where the heat produced can be utilised. However, even with a small CAD facility the socio-economic benefits are significant at €230,000pa. (This value would increase if the CAD processed material that would otherwise go to landfill). The socio-economic benefits of the case study are

- GHG emission savings of 3,700 (71kg CO_2 equivalent/ton biomass treated)
- 72tpa of Nitrogen fertiliser saved (1.4kg/ton biomass treated)
- A saving in production costs for farmers of €10/ha
- 18tpa of Nitrogen leaching to groundwater saved (€1.25/ton biomass treated)
- All obnoxious smells from spreading

Unpredictable changes in legislation and a lack of long term vision and planning, make it very difficult to develop a CAD facility which takes 3-5yrs to develop.
Unless Ireland adopts spreading rules, similar to other EU countries, it is unlikely any CAD facilities will be built in Ireland.

Assumptions used for calculations

Table 10.10. Assumptions used for calculations

Carbon value	€20/t CO_2
Required storage capacity solid manure in mths, reference	9
Required storage capacity liquid manure in months, reference	4
Required storage capacity fiber fraction in months, case study	2
Required storage capacity liquid manure in months in case study	6
Price, electricity sold, € per kwh	0,072
Price, electricity, own production for process purposes, € per kwh	0,072
Price, heat sold, € per Mwh	20
Capacity of trucks in use, tones, solid/liquid manure/liquor	20/30
Average speed, transport vehicles local roads, km/h	30
Average speed, transport vehicles long distance transport, km/h	60
Liquid manure transportation to and from the CAD €	1,70
Solid manure transportation to the CAD €	2,70
Long distance transportation €	4,80
Average distance from farm storage to spreadland , km	0,75
Average distance from farm to CAD, km	4
Average distance, long distance transport, sludge/fibre, km	10/50
Interest rate	5.5%
Avoided obnoxious smell (cost difference for soil injection) €/t	0,50
Reduced N leakage to groundwater (=25% saved N fertiliser) €/kg	3.36

Biogas in Belgium

Environmental and socio-economic analysis of the setting up of a centralised co-digestion plant in the Walloon Region - Belgium

By Fabienne Rabier and Gaëlle Warnant

Background and Objectives

Centralised co-digestion (CAD) for the production of electricity and heat is not well developed in Belgium. As there is a real interest for biogas production from agricultural and industrial sectors, there are several non-technical barriers that hinder the development of biogas production in the Walloon Region. Even if the Green Certificates mechanism encourages the production of electricity from renewable sources, this system may not be fully adequate for the production and use of biogas. Because of a lack of knowledge and experience in Belgium it was interesting through PROBIOGAS project to transfer socio-economic methods elaborated in Denmark were the CAD concept is developed for more than 20 years. By adjusting the models to a selected case study the project tends to integrate some externalities linked to CAD plant and to assess costs and benefits for the society as a whole. By increasing awareness about the CAD technology and advantages for different sectors, the PROBIOGAS project may help to remove some brakes and to implement this concept in Belgium.

Belgian case study: the selected area

Despite the livestock intensity (concentrated in some areas) and the hardening of the law concerning the fertilization with organic nitrogen, Wallonia has still a potential for manure spreading as the soil binding rate is lower or equal to 1 for more than 80% of the farms. [2]

The selected area is situated in the Province of Liège in the Walloon part of Belgium. It is characterized by the concentration of cattle breeding (more than 35000 in production) and especially dairy cattle. The localisation of pig and poultry breeding is much more variable.

Most of the land is dedicated to meadows and the main cultivated crops in this area are fodder maize and cereals.

The number of food industries is also important linked to the density of the population that is high around Liège. Food-industries process mainly dairy products, cheese, fruits (syrup and cider), cereals and starch.

Furthermore, farmers of this area and some local authorities are interested in biogas production as 2 biogas projects started in 2005 in the communes of Sprimont (20 farms) and Limbourg (around 20 farms).
For the Belgian case studied in PROBIOGAS it was chosen to merge the data of both projects in order to get sufficient amount of biomass feeding the digester. In total 40 farms have taken part in the study which represents an area of 2208ha. 41 local food-industries were contacted but response rate was very low (11 out of 41). Because a big part of their by-products is already used for animal feeding and low treatment costs, few industries are currently motivated by treating their wastes by anaerobic digestion.

Technical aspects of the biogas plant

The CAD plant of the Belgian case study will have a treatment capacity of 75000 tons a year or approximately 205 tonnes per day. The plant is operated at thermophilic temperatures (around 52 – 55°C) with a 15 days retention time. The plant is equipped with a sanitation tank where effluents are heated to 70°C for one hour. After this step, the biomass is pumped through a heat exchanging system to be introduced into the digester (3100 m³ capacity). After 15 days the digested manure is pumped into a storage tank from where it can be loaded on trucks and driven back to storage at farms. The biogas produced is cleaned by biological process and sent to the CHP (combined heat and power generation) facility.

Table 10.10. Categories and amount of biomass, biogas yield from different biomass sources

BIOMASS	Type	Amount	DM	DM	VS	CH_4 yield
		t/ year	g/kg	kg/y	kg/y	Nm³/y
Cow manure	slurry	43236	71	3069756	2455805	491161
	deep litter	4651	278	1292978	1034382	155157
Pig manure	slurry	8056	102	821712	657370	197211
Horse manure	deep litter	180	300	54000	43200	8640
Poultry manure	deep litter	2268	550	1247400	997920	349272
Total cattle manure		58391		6485846	5188677	1201441
By-products from industries		16600		1391600	1113280	328824
Total		74991		7877446	6301957	1530265

As shown in Table 10.10, methane (CH_4) production is estimated to 1 530 265 Nm³ a year which is 20 Nm³ per ton of biomass treated. This relatively low methane yield is due to the low ratio of organic waste and to the low methane potential of the effluents treated. Adding energy crops and other substrates with high dry matter content and high specific methane potential could increase methane yield. Figure 10.1 shows the contribution of each substrate to the biogas production in the hypothetical Belgian case and reveals a significant increase in CH_4 production if energy crops would be included.

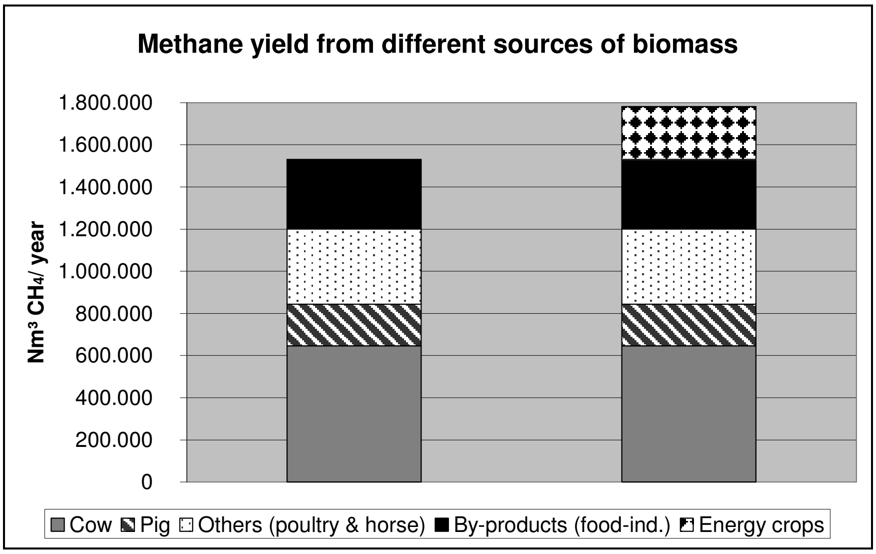


Figure 10.1. Annual methane production from different types of biomass

The CHP engine of 800 kW_e converts energy into electricity an heat with shares of 37 % for electricity or 5 500 000 kWh that can be sold to the grid. Heat production amounts to 52% but out of a total of 7 900 000 kWh produced only 2 900 000 kWh can be sold to external users.

Substrates management and agricultural aspects

Through anaerobic digestion (AD) digested slurry has an increased fertiliser value compared to untreated manure. This change is due to the mixture of different animal effluents (pig slurry, cow slurry and solid manure) and to the addition of industrial by-products of various composition. Furthermore, through the process of AD, part of the organic nitrogen is broken down with in final an increase of the mineral nitrogen (ammonium) that is more easily available for the plants. This change can have a significant consequence on fertilization plans. Receiving digested manure, farmers can save money on the purchase of mineral fertilisers.
Calculations have been carried out in order to assess the impact of the CAD system on the fertilisers' application. The demand in nitrogen, phosphorus and potassium are based on the fertilisation recommendations in force in the Walloon Region. The size of the area required to receive manure is calculated on the amount of phosphorus that is allowed applying.

As additional biomass is processed into the digester the volume of digested manure exceeds the volume of manure delivered to the plant. The surplus digestate has to be exported to an 812 ha area. It is assumed that the crops production farms are willing to use digested manure instead of mineral fertilisers. On the other hand, farmers delivering manure to the biogas plant would receive an equal quantity of digested manure that they have provided. Effects on fertiliser purchase and use are detailed in Table 10.11.

Table 10.11. Digestate application and savings on fertilisers purchase

Animal production farms	
Total area (ha)	2 208
Digestate to be spread (t/y)	52 791
Savings in mineral fertilisers (€/y)	16 890
Crops production farms	
Total area (ha)	812
Digestate to be exported (t/y)	22 200
Savings in mineral fertilisers (€/y)	65 569
Total savings in mineral fertilisers (€/y)	82 459
Savings per ha (€)	27

There is a great disparity between animal production farms and plant production farms as that highest saving is for arable farms with 81 € per ha while saving is only 9 € for animal farms. Animal breeders have to spend more buying phosphorus and potassium as P and K contents in digested manure are lower than in untreated manure.

Economic performances of the biogas plant

Treatment capacity and biogas production are the main parameters determining the dimensions of the plant. The assessment of these parameters is based on Danish methods and allows the projection of planning and calculations of the required investments. The economic performance of the plant also depends on preconditions as energy prices and treatment fees that the biogas plant would receive from local industries (Table 10.12).

The profitability of the biogas plant is calculated on costs and sales of electricity and heat including the income from Green Certificates. The Green certificates (GC) is a transferable certificate issued to producers of green power for a number of kWh generated which is equal to a certain amount of energy divided by the CO_2 saving rate. The CO_2 saving rate is calculated by dividing the quantity of CO_2-saving achieved by the use of electricity and heat from biogas by the CO_2 emissions of a traditional reference system. At present on the Walloon market the value of the GC is around 90 €/GC. However, as the green electricity market shows some uncertainty it was chosen for this study to use the minimum value guaranteed by regional authority of 65 € per GC. In the present case study it was calculated that 1.24 GC is given for one MWh_e based on biogas. An extra income of 80 €/MWh is given for every MWh_e supplied to the grid.

Table 10.12. Basic preconditions and investment costs in the Belgian case

Treatment capacity (t/d)	200
Biogas yield (Nm³/t)	20
Electricity sale price (€/MWh)	25
Heat sale price (€/MWh)	30
Value of Green Certificate (€/MWhe)	80
Treatment fee for organic waste (€/t)	4,8
Investment for biogas plant (million €)	3,9
Investments for CHP facility (million €)	0,5
Total Investment costs (million €)	4,4

The CAD system covers transportation costs for manure and digestate. In this case trucks are hired from an external supplier. The system also meets the costs for storage of digestate. Table 10.13 shows the average profit of the CAD in 2005 prices. Costs were calculated in Danish 2005 prices and then converted into Belgian 2005 prices by using Comparative Price Levels from Eurostat. An interest of 5,5% is used.

Table 10.13. Average yearly profit of the CAD of the Belgian case

Item	€/y
Transportation costs	-209000
Storage of digestate	-19000
Profitability of the biogas unit	88000
Profit of the CAD system	-140000
Profit if biogas production increased by 10%	-90000
Profit if biogas production decreased by 10%	-190000

Even if farmers' savings are taken into account, the system is not quite economic being disadvantaged by low biogas production and the little part of the heat that can be sold. If additional substrates with high methane potential were supplied, the profitability of the plant could be improved.

Socio-economic analysis

The socio-economic analysis differs from the previous economic analysis by looking at the CAD system from the society point of view and by taking into account implications for different sectors. In this part the objective has been to quantify and monetize some externalities that derive from an imaginary biogas plant given the context of the selected case in Wallonia. Environmental benefits as reduced risks of eutrophication of ground water, mitigations of green house gas (GHG) from the management of manure and organic wastes and substitution of fossil fuels for energy production are important effects that are worth assessing in order to emphasize the advantages of the biogas scheme alternative compared to the "business as usual" situation.

Four different levels were analysed where the base level (R0) does not include any externalities and the highest level (R3) includes all externalities that could be quantified and monetized in the present case. Some externalities have to be assessed using Danish data and others, such as veterinary aspects, could not be quantified because of the lack of specific data available.
The 4 levels that were analysed in the Belgian case can be described as follows:
Result 0: Energy production from biogas plant (no externalities included).
Result 1: Benefits for agriculture and industries (from manure and waste management).
Result 2: Environmental externalities linked to GHG emissions (CO_2, CH_4, N_2O) and reduced nitrogen losses included.
Result 3: Value of obnoxious smells reduction and income via Green Certificates included.

Including a socio-economic value for Green Certificates can be a delicate matter as the GC system may cover different aspects such as GHG reduction. In this analysis it has been assumed that the GC value only relates to benefits for the society in terms of 'security of energy supplies and political stability issues'. In order to prevent double counting or inconstancy, integration of a GC value is taken into account in R3 and is assumed not to include other aspects included in lower levels like the value of mitigation of GHG emissions (R2).

The estimated effects on GHG emissions linked to the CAD alternative is showed in the Table 10.14. CH_4 and N_2O emissions are expressed in CO_2-equivalent using their respective Global Warming Power (GWP). For a time horizon of 100 years, the GWP of CH_4 is 21 times higher than that of CO_2 and GWP of N_2O is 310 times higher than that of CO_2.[3]

In total 3845 tons of CO_2-equivalent can be saved by the deployment of the CAD system. It can be seen that 46% of the total CO_2 emission reduction is due electricity sales assuming biogas would substitute natural gas. Heat sales contribution to CO_2 emission reduction is 24%. The use of digested manure instead of mineral fertilisers contributes to a CO_2 reduction of about 742 tons of CO_2-equivalent.
Other reductions derive from biomass management and anaerobic digestion, which lead to lower CH_4 and N_2O emissions. A reduction of about 10 tons of CH_4 is achieved by farms meanwhile 6 tons of CH_4 are saved through the treatment of industrial by-products. Un-burnt CH_4 from the CHP-motor system has been assumed to be 1% of the total of CH_4 produced. This represents an increase in CH_4 emissions of 11 tons. In total the reduction of CH_4 emissions is about 115 tons of CO_2-equivalent and contributes to 3% of the total. The reduction of N_2O emissions achieved by manure and waste treatment amounts to 1,635 ton of N_2O or 507 tons CO_2-equivalent.

Table 10.14. Consequences on GHG emissions of the biogas plant in the Belgian case study

CO_2	Alternative – Reference (ton CO_2)	Equivalent CO_2 % - split
Gas sales	0	0
Electricity sales	-1762	46
Heat sales	-920	24
NPK substitution	-742	19
Transport fuel	201	-5
CO_2- equivalent	-3223	84
CH_4	Alternative – Reference (ton CH_4)	Equivalent CO_2 % - split
Animal manure	-10	6
Industrial by-products	-6	3
CHP-plant unburnt	11	-6
Total CH_4	-5.5	
CO_2- equivalent	-115	3
N_2O	Alternative – Reference (ton N_2O)	Equivalent CO_2 % - split
Animal manure & other substrates	-1.635	
CO_2- equivalent	-507	13
GHG in total		
Mitigation in CO_2-equivalent	-3845 ton CO_2 equivalent	100
Specific CO_2 reduction	51 kg CO_2 equivalent/ ton biomass	

Consequences of GHG emissions have been monetized and integrated into the calculation of the socio-economic performance of the plant. The socio-economic costs and benefits for the CAD alternative were based on forecasts of fuel and energy prices developed by IEA (International Energy Agency) and DEA (Danish Energy Authority) for the period 2006-2025. Prices for electricity purchase and sales and prices for heat sales are based on Belgian data. The contribution of energy sales to the socio-economic results is showed in Table 10.15.

Table 10.15. Annual Energy production and sales, preconditions used in the Belgian case (national price level €/ MWh)

CH_4 production (Nm³ /y)			1530265
	Electricity	Heat	Green Certificates
Price level (€/MWh)	34	30	80
Production (MWh/y)	5500	7900	
Net production sold (MWh/y)	3097	2948	3097
Incomes (million €/y)	0.105	0.088	0.250

Because specific data from Belgium were not available the monetization for reduced N-losses to ground water has been calculated on Danish assumptions: N-leakage reduction is 25% of saved N- fertiliser, monetized by the value of 3,36 €/kg N. In the Belgian case, the value of reduced N-leakage is equivalent to 61 141 € per year. Table 10.16 presents annual costs and benefits for the CAD alternative according to the 4 levels analysed.

Table 10.16. Annual socio-economic costs and benefits (4 levels of externalities integration)

Costs as annuity (mil. €/y)	R0	R1	R2	R3
Invest. biogas plant	0.359	0.359	0.359	0.359
Invest. CHP plant	0.044	0.044	0.044	0.044
Transport	0.027	0.027	0.027	0.027
Operation & maintenance	0.278	0.278	0.278	0.278
Total costs	0.708	0.708	0.708	0.708
Benefits as annuity (mil. €/y)	R0	R1	R2	R3
Electricity sales	0.105	0.105	0.105	0.105
Heat sales	0.088	0.088	0.088	0.088
Incomes from Green Certificates				0.250
Storage/handling/distribution manure		-0.157	-0.157	-0.157
Improved fertiliser value		0.087	0.087	0.087
Transport saving at farms		-0.006	-0.006	-0.006
Savings on by-products treatment		0.062	0.062	0.062
Value of GHG reduction			0.078	0.078
Value of N-losses reduction			0.061	0.061
Value of smells reduction				0.026
Total benefits	0.194	0.180	0.319	0.594
Profit (benefits – costs)	-0.514	-0.529	-0.390	-0.114

It is seen that even on the highest level including all the estimated externalities (R3), the studied biogas scheme is not economic from the socio-economic point of view and the annual deficit is estimated to 114 000 €/y. Nevertheless, if all heat produced on site could be sold substantial incomes could be expected. Additional waste supplies would increase biogas production and thus the profitability. It also should be mentioned that considering the current price of Green Certificate (around 90 €/GC) would imply break-even point at the R3.

Non technical barriers and recommendations

The development of CAD in Denmark was favoured by a set of preconditions in terms of legislative incentives as well as economic aspects. Such expansion of biogas production in other regions like in Wallonia is not feasible until non technical barriers specific to the national and regional context could be identified and partly removed.

Legal and administrative procedures are very complex, often progressing slowly. As many steps of CAD projects come under various authorities it is quite long obtaining clear information and authorizations.

The constant supply of substrates of good quality and in large quantity in a minimum radius around the plant is often problematic. Better collaboration between industrial and agricultural sectors could allow the pooling of sufficient amount of substrates ensuring a profitable biogas production. Drawing-up a positive list of authorized substrates could increase the supply of organic matter to raise methane yield. Furthermore, a clear regulation about the authorised substrates with a rationalization of controls may loosen the current *strong restrictions on the use of digestate* by simplifying application and control procedures that are heavy and costly.

In many cases *the lack of heat market* is a brake for the profitability of a biogas unit. Programmes or public subsidies to encourage the installation of district heating may favour an efficient use of the heat. Income from the production and sales of heat produced from a renewable source should not be linked to the green electricity production.

Because of a *poor awareness of the benefits of biomethanation* local people are often afraid of nuisances and can reject some biogas projects. Giving credible information about the impact of biogas plants could prevent such scepticism.

Externalities are not commonly assessed and monetized. Meanwhile, environmental and socio-economic benefits resulting from biogas production should be better integrated by means of financial plans supporting sustainable development.

Conclusion

As many advantages from centralised co-digestion have been demonstrated through research and demonstration programmes in Denmark, PROBIOGAS project has shown that the CAD concept could generate environmental and socio-economic benefits and should develop in other European regions under specific conditions. The present study of an hypothetically CAD plant in the Walloon Region has revealed some limitations as the whole system would not be economic even if all the quantified and monetized externalities that could be assessed within this analysis were integrated. The Belgian case is disadvantaged by the low biogas potential of the substrates and difficulties to pool by-products from external industries. However, the production and use of renewable energy is favoured by the Green Certificates system which can raise substantial income to the biogas plant if additional heat was marketed and sold. The Belgian case study has brought to light advantages for agricultural community in terms of management of effluents and savings on purchase and use of mineral fertilisers. Significant impacts on the mitigation of GHG emission and the security of renewable energy supply via biogas production are important externalities that may encourage decision makers as well as other biogas actors to remove the existing non-technical barriers that hamper CAD development in the Walloon Region.

11. Dissemination of project results

The PROBIOGAS project organized a European Biogas Workshop the 14-16 June 2007 in Esbjerg, Denmark. The workshop was the 3rd in a series of successful biogas workshops, organized under the name "The future of biogas in Europe" by the Bioenergy Department, the University of Southern Denmark in Esbjerg. This year, the workshop presented, an overview of the European biogas situation and an important part was dedicated to the main results of the assessment work of the PROBIOGAS project as well as the evaluations of European biogas experts concerning the present, the main trends and the future of the Biogas in Europe.

Eighty-five persons from twenty-one countries attended the two days of oral sessions of the workshop and sixty five of them joined the study trip organized the following to biogas sites in Jutland, Denmark.

The proceeding report and the oral presentations as well as more information about the workshop and study tour are available at the web page of the Bioenergy Department, University of Southern Denmark: www.sdu.dk/bio

12. Impacts, lessons learnt and conclusion

There is a remarkable potential for biogas production from centralised co-digestion in all the six case study regions. If the non-technical barriers are removed, biogas plants might be successfully established and operated. As the unfavourable legislative framework was recognised as one of the main barriers for the development of biogas in the assessed regions, a movement for removal of the non technical barriers has started in all the cases. The national partners, together with the members of the target groups, are determined to bring the message further to the legislators, in an attempt to improve the national biogas policy and to create better legislative framework for its development.

A rise in awareness of the value of manure as a fertiliser has been achieved in general. Furthermore an awareness of anaerobic digestion as a mean to increase the nutrient value of manure. During the whole duration of the project, farmers involved in biogas projects showed interest for the project, were willing to give information and to collaborate and were very interested to get the final results. The assessment study has showed significant and positive impacts from the integration and monetisation of the externalities (related to biogas projects) and many members of the TGN and different actors of biogas sector have showed great interest in the approach of estimating and integrating biogas externalities.

The assessment and integration of biogas externalities through costs/benefits analysis could influence policies in this area. Collaboration and synergies between actors from different spheres of activity are crucial for the success of such projects and four are indispensable:

1. Awareness and knowledge dissemination
2. Favourable legislation
3. Economic incentives for stake holders
4. Involvement and motivation of farmers and other main actors

By the end of the project development, the market prices for electricity produced on biogas increased significantly in several partner countries. Although it was too late to include the new prices in the assessment calculations, this is a very promising starting point for the development of biogas technologies in these countries. The legislative frame affecting the biogas sector have been improved in countries like France, Spain and better economic premises were bought about for biogas from anaerobic digestion by higher electricity prices for the produced electricity on biogas, while in the Netherland and Ireland there is a possibility to rethink the restrictive legislation about the utilisation of digestate and the substrates that are allowed to be co-digested due to re-opening the political debate concerning the benefits and the perspectives for biogas development in these countries. In Greece it is the first time that farmers are actually getting information about the economic and socio-economic significance of internalising the externalities of biogas. It is estimated that there is a good chance that in the Midi Pyrenees case study, the target groups and the project partner, the SOLAGRO Company, will succeed in the years to come to actually start a project generation activity for the establishment of a biogas plant.

The implementation of the project itself is considered by its promoters to be a success, with highly relevant outcomes, significant European impact and with a number of lessons learnt. The project partners did a great job finding solutions to a range of problems encountered during the progress of the project, providing quality input and disseminating the results of the project at national and international level.

The project had a great European impact, expressed also by the large number of enquiries received by the coordinator during the whole project period and the fact that the project was mentioned as a source of inspiration by other project proposals (AGROBIOGAS, BIG EAST). The final European Biogas workshop and study tour "The future of biogas in Europe III" organised by SDU in Esbjerg was very well attended. There were a lot of interesting discussions during the oral sessions and the social programme and intense interest among visitors at the study tour was shown as well. After the workshop there was an overwhelming amount of feed back from the participants, expressing their satisfaction about the organisation and the outcomes of the workshop.