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Järna den 19 december 2004

Redovisning av Biogasanläggning

byggd av Stiftelsen Biodynamiska Forskningsinstitutet på Yttereneby i Järna

Inledning

Stiftelsen biodynamiska forskningsinstitutet startade byggandet av biogasanläggningen under 2002 med hjälp av statliga investeringsstöds pengar. Anläggningen var färdigbyggd och kunde börja provköras i november 2003 (Bild 1). Ansökan om stöd var utarbetad med den anläggning som nu finns färdigbyggd på Nynäs gård utanför Trosa som förebild. Byggkostnaden beräknades till 2 500 000 kronor varav halva summan finansierades med hjälp av det statliga stödet i samverkan med Södertälje kommun medan den andra delen av Biodynamiska forskningsinstitutet genom lån från Ekobanken. Som säkerhet för lånet i ekobanken erhölls borgen och ställda säkerheter från en borgenkrets bestående av enskilda personer och institutioner med ankytning till de biodynamiska verksamheterna i Järna. Lånet återbetalas nu under 10 år från är 2004 vilket jämte räntekostnader och driftkostnader skall täckas av försåld gas. Hittills har amorteringar och räntekostnader fått täckas av Biodynamiska forskningsinstutets övriga verksamheter då anläggningen ännu inte uppnått erfoderlig produktion av gas till försäljning.

Bild 1. Tvåstegs biogasanläggning uppförd av Stiftelsen Biodynamiska Forskningsinstitutet på gården Yttereneby i Järna (Foto hösten 2003, Winfried Schäfer).

Anläggningens konstruktion

Efter grundliga förstudier med besök på anläggningar i Sverige och Danmark beslöt institutet att modifiera den ursprungliga konstruktionsplanen till en tvåstegsanläggning efter förebild från den anläggning som byggts på Önnestad lantbruksskola. Ett viktigt motiv för detta val är att här rötas fast gödsel samt att fast gödsel erhålles som slutprodukt och som i sin tur också kan rötas. Därutöver erhålles också en flytande slutprodukt vilken har samma egenskaper som urin och kan också användas för gödslingsändamål.

Anläggningen är anpassad för att taga emot gödsel från 55 kor plus rekrytering från gårdarna Skilleby och Yttereneby vilket (ca 600 ton per år) plus ytterligare organiskt material från storkök och livsmedelsförädling.

Rötningen sker i två steg. Mellan dessa två steg sker en separering där den fasta delen frånskiljes enligt flödeschemat i figur 1. I det första steget sker en hydrolys varvid organiska syror bildas samt en del metangas. Efter separering pumpas den flytande fraktionen till steg där den slutliga rötningen sker. Materialflödena framgår av figur 2.

1. Fast gödsel som består av en blandning av djurgödsel, halm samt av halmen uppsugen urin, förs ut via utgödslingskanalen in i biogasanläggningens reaktor.
2. Fastgödseln matas kontinuerligt in i reaktortuben 1 via en kanal som mynnar ut i reaktorns övre del och som matas ut från botten efter en uppehållstid på ca två veckor.
3. Utmatning av rötad hydrolyserad stallgödsel sker vi en rörlig låda som för ut gödseln satsvis från reaktorn.
4. Den rötade stallgödseln fasta del separeras från genom en skruv med en separator som pressar ut den flytande delen.
5. Den rötade fasta gödseln lagras på gödselplattan för att senare transporteras för anläggning av komposter.
6. Den efter separering flytande gödseln rinner till
7. en behållare för mellanlagring och
8. pumpas därefter till
9. reaktortub 2 som också kallas metangasfilter. Denna är fylld med fyllkroppar. Här sker den slutliga metangasjäsningen varefter den flytande rötdelen pumpas till en
10. urinbrunn.
11. Biogas som under tryck frigörs från både steg ett och två går via rör till lagringsbehållaren för biogas som består av en expanderbar säck lagrad i en kontainer.
12. I ladugården separerad urin transporteras till en
13. brunn för lagring av ej rötat urin.

Anläggningens tekniska delar framgår i mera detalj av figur 3 och gasflöden framgår av figur 4.

En del av gasen åtgår till anläggningens egen värmeförsörjning. Värmekällan består av en gasdriven värmepanna och vattenburen värme tillförs medels värmeslingor till de båda reaktortuberna så att temperatur på 35^{o}C kontinuerligt kan upprätthållas för processen.

Styrning av temperatur, matning in och ut av gödsel och rötmassa, samt vätskeströmmar regleras av inkommande data från olika delar av anläggningens funktioner med hjälp av ett för ändamålet utformat dataprogram.

Anläggningens funktion och hittills uppnådda resultat

Biogasproduktionen under det första driftåret 03.11.15 – 04.05.08 framgår av figur 5. Medelvärdet av biogasproduktionen uppgick till drygt 40 m3 per dygn. Denna relativt låga produktionen förklaras av flera avbrott, i januari tillföljd av en frusen gasledning och ett gasläckage i april 2004. Under mars månad närmade sig produktionen en nivå som motsvarar förväntad produktion för att anläggningen skall börja betala sina kostnader. Med tillägg för ytterligare tillfört organiskt material avsågs biogasproduktionen enligt den på förhand uppgjorda kalkylen kunna uppgå till 22 000 m3 efter det att en del av gas använts för anläggningens egen uppvärmning. För detta krävs en produktionsnivå överstigande 150 m3 dygn under 200 dagar på året. Hösten 2004 låg produktionen på en betydligt lägre produktionsnivå vilket visade bero problem med uttorkning av en del av rötmassan i reaktortuben varför anläggning var tvungen att stoppas och substratinnehållet tömmas och nystart som beräknas ske under december. Separatorn har nu också bytts ut. Utrustning för hygienisering av matavfall håller också på att installeras så att anläggningen beräknas kunna komma i full drift under februari med tillskott också av livsmedelsavfall i enlighet med de ursprungliga planerna.

Ekonomisk redovisning

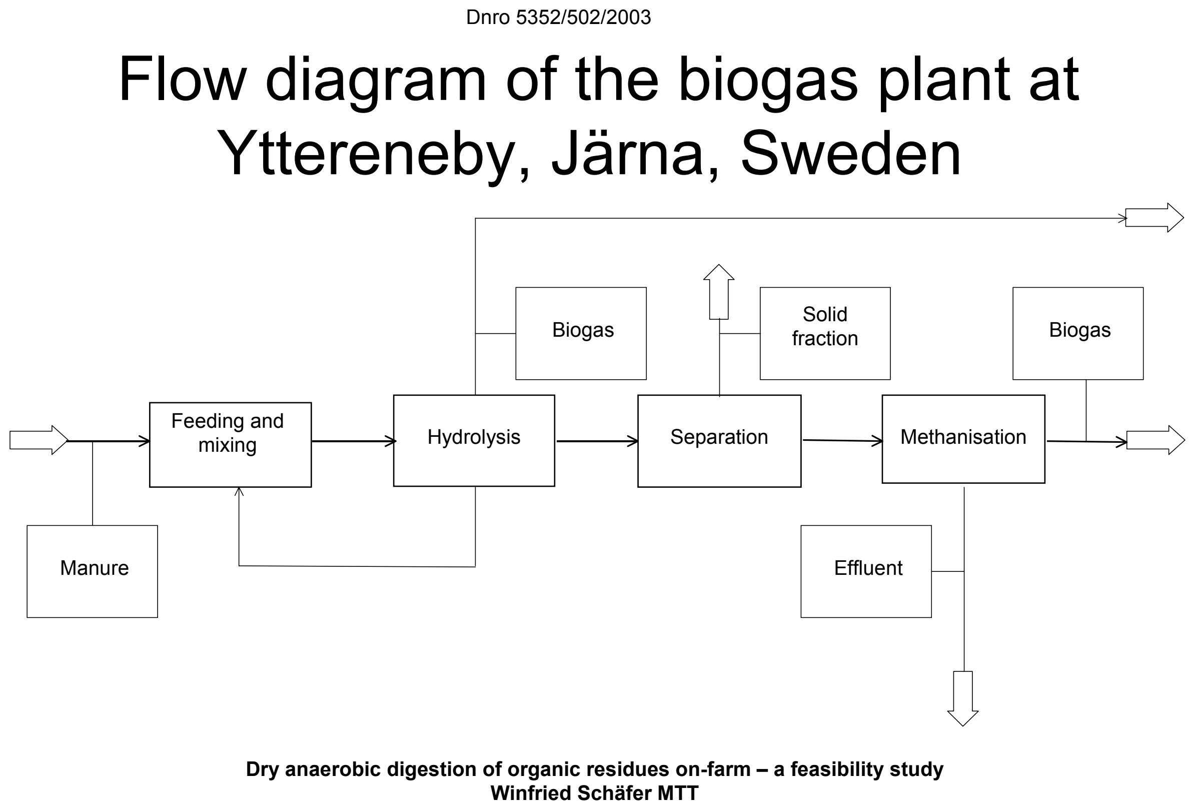
Den bokförd investeringskostanden fram till 2004-06-30 uppgick till 2 976 202 kronor. Till detta kommer lönekostnader för Lars Evers på halvtid under 2004 på kr 175 000. Tilläggsinvesteringar under det andra halvåret av 2004 uppgår till ca 50 000.

Fram till 03.08.30 då utbetalningarna av LIP anslag avslutades uppgick den totala investeringen till kr 2 519 288 som fördelades på

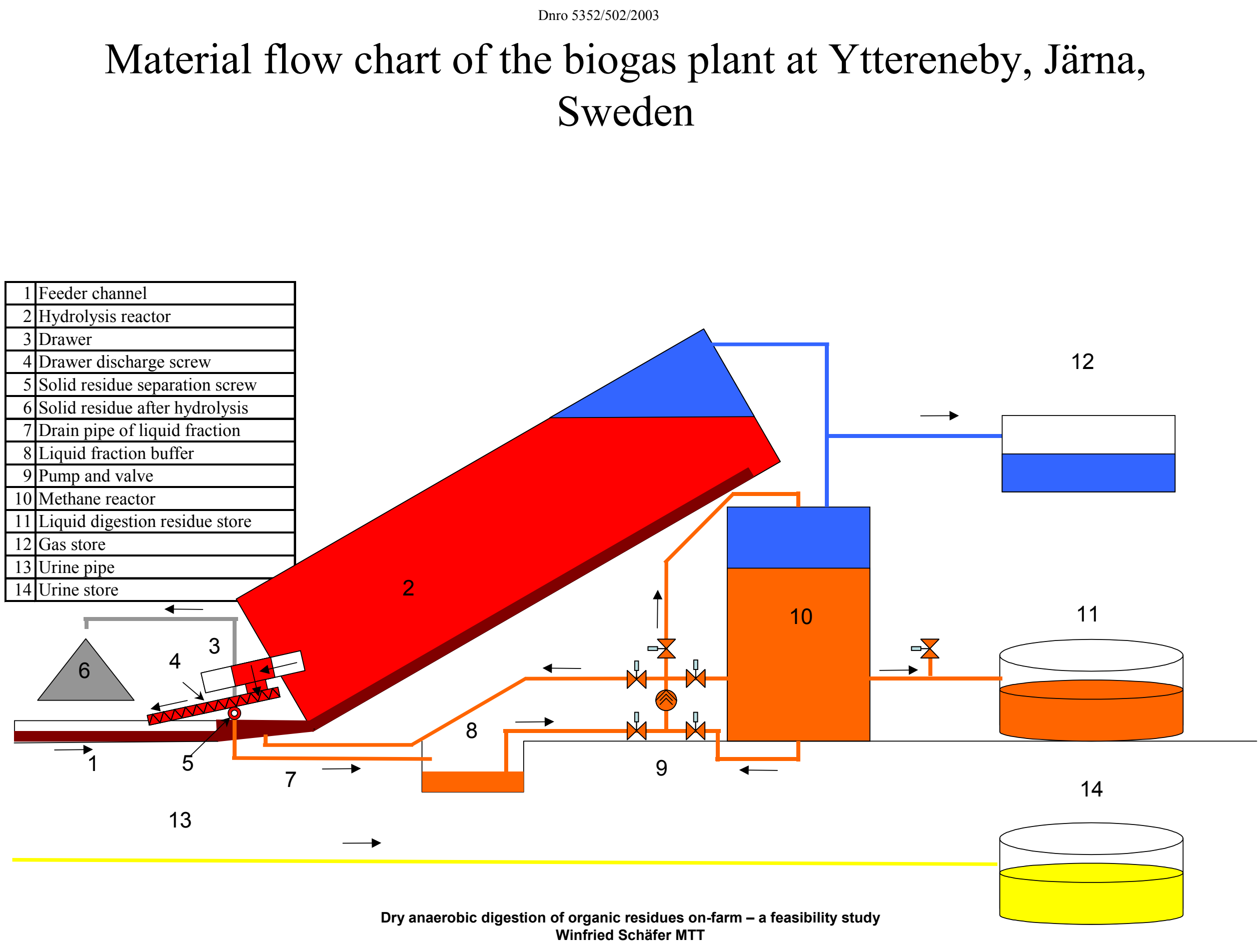
Materialinköp	kr	742 143
inköpta tjänster	kr	1 334 009
löner	kr	432 412
övrigt	kr	10 618

Utvärdering

Utvärdering av anläggningen pågår inom ramen för ett samarbete med Finland (Bilaga 1). Utvärderingen finansieras av Finska staten via det finska lantbruksministeriet och Agrofood Research som tillsamans satsar 90 000 euro ca 800 000 kr. I Överenskommelse skall vi från Sverige därutöver bidraga med 15000 euro. Trots den stora insatsen från finsk sida har den svenska energimyndigheten avslagit ansökan om bidrag till detta. Tillsvidare får bidynamiska forskningsinstitutet bära även denna kostnad. Resultaten från denna utvärdering kommer att presenteras vid en forskarkonferens vid universitet i Kassel (bilaga 2) samt antagligen också IFOAM:s (International Federation Of Agricultural Movment) världskonferens i Australien september 2005.

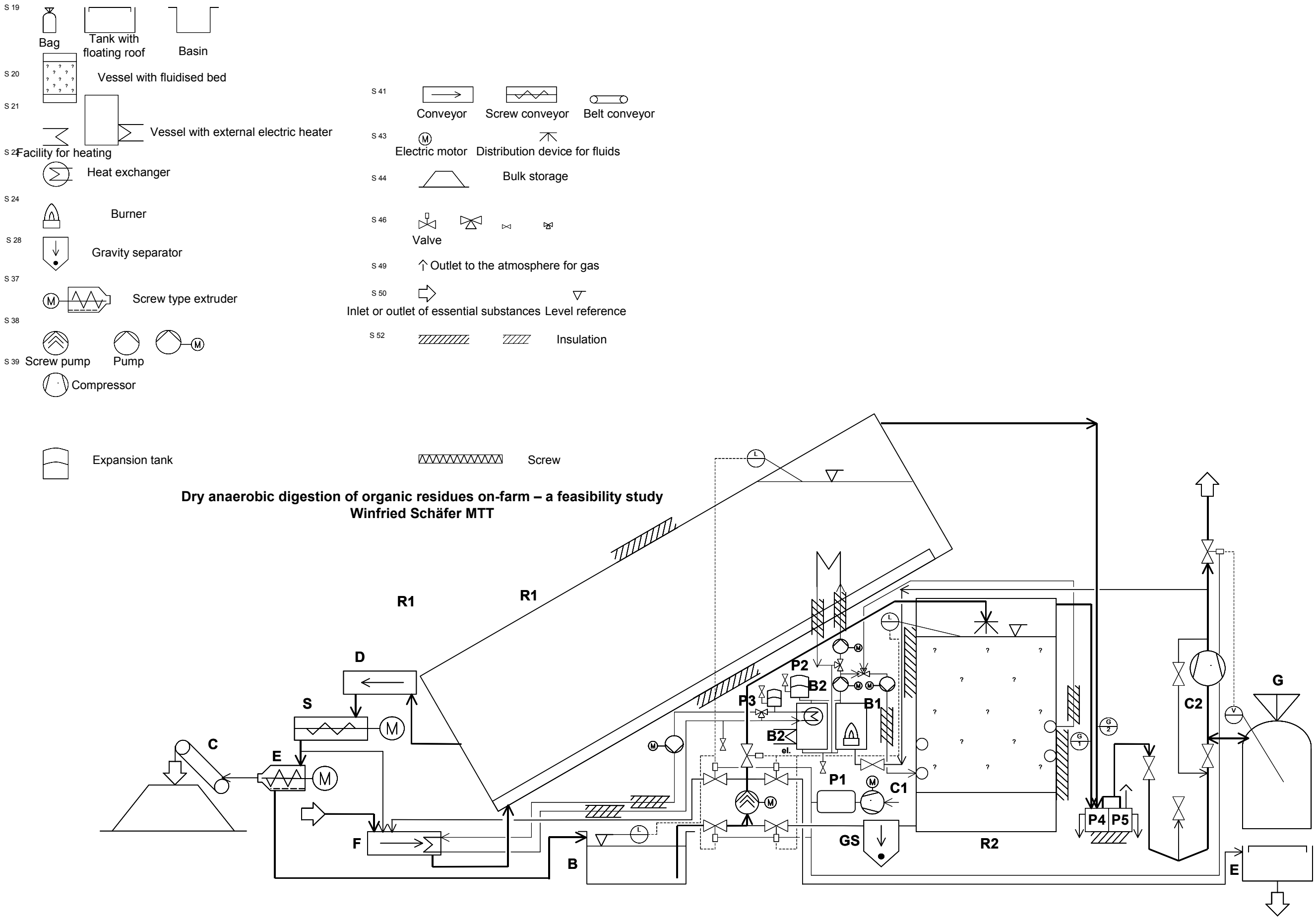


Figur 1. Flödesdiagram för biogasanläggning på Yttereneby i Järna



Figur 2. Materialflödesbild för biogasanläggning på Yttereneby, Järna

Graphical symbols EN ISO 10628



Identification number	F	R1	D	S	E	C	B	R2	GS	E	P4	P5	G	C2	B1	B2	C1	P1	P2	P3
Denomination	Feeder	Hydrolysis reactor	Drawer	Discharge screw	Separation screw	Belt conveyor	Buffer	Methane reactor	Granulate separator	Effluent store	Dewatering	Dewatering	Gas bag	Gas compressor	Gas boiler	Electric boiler	Air compressor	Pressur air tank	Expansion tank	Expansion tank
Technical data																				
Pressure Mpa																				
Temperature C																				
Material																				
Note																				

Dry anaerobic digestion of organic residues on-farm – a feasibility study
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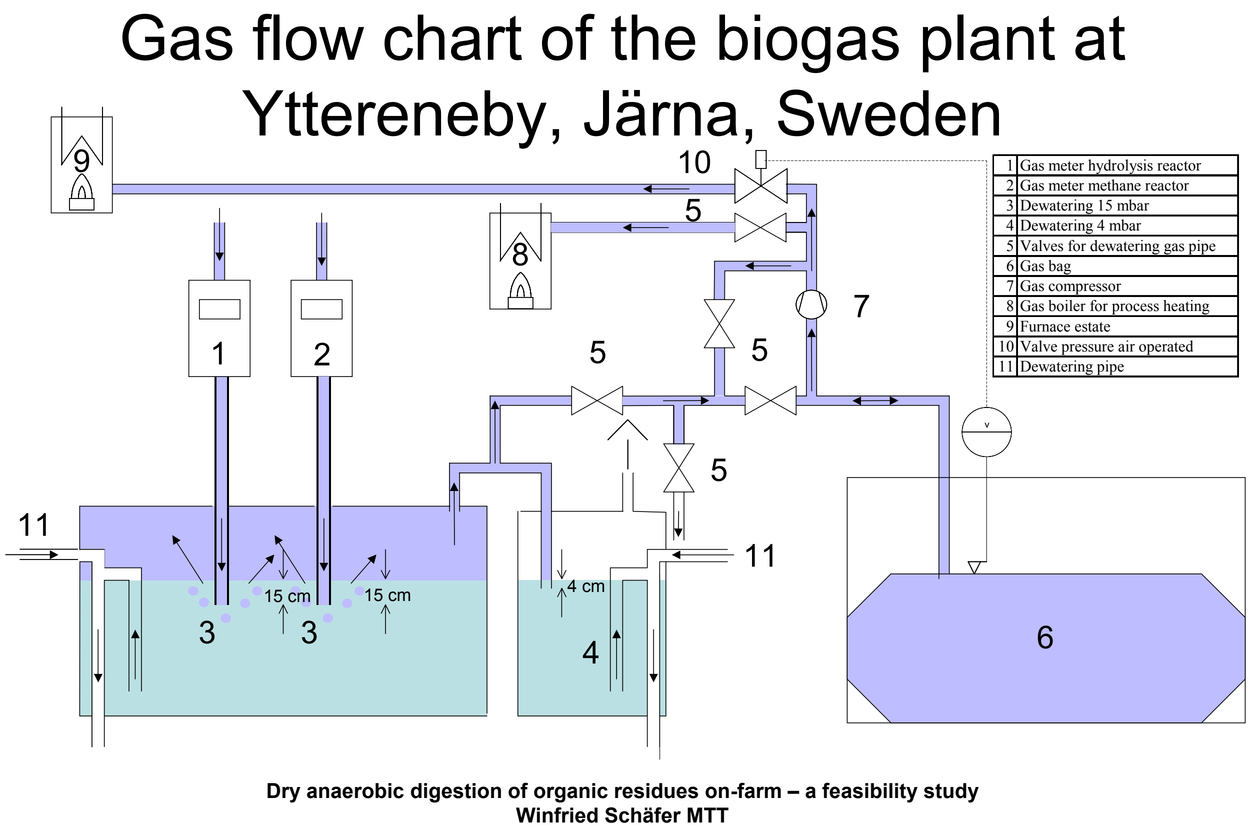
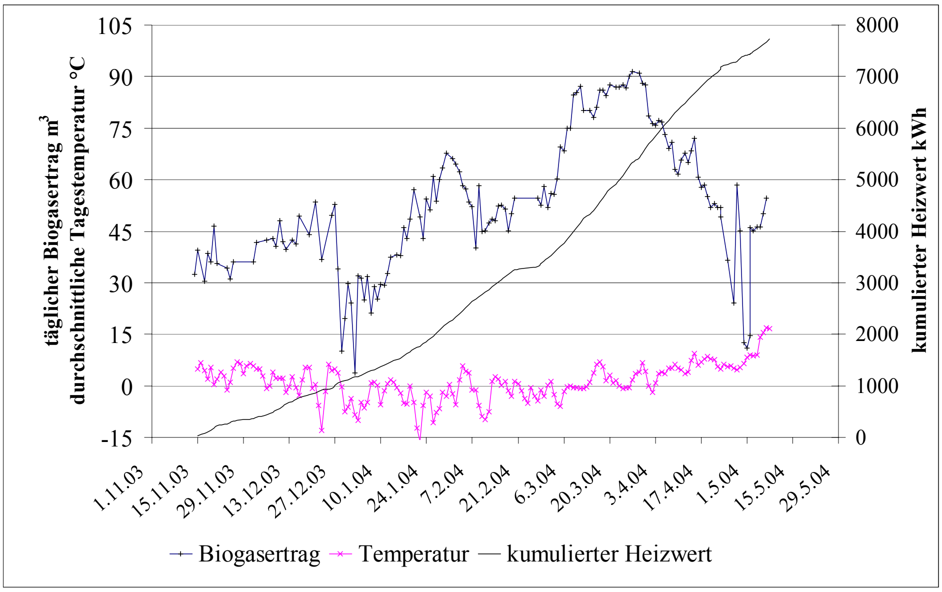
Figur 3. Teknisk beskrivning av biogasanläggning, Yttereneby, Järna



Figur 4. Gasflöden för biogasanläggning, Yttereneby, Järna.



Figur 5. Biogasproduktion m^3 , temperatur °C och ackumulerad värmevärde kWh 03.11.15 – 04.05.08 biogasanläggning, Yttereneby, Järna (Schäfer, Evers, Lehto, Sorvala, Teye och Granstedt, 2004)

Dry anaerobic digestion of organic residues on-farm - a feasibility study

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Abstract

Background

European countries are committed to reduce CO_2 emission originating from fossil fuels. On-farm produced biogas may replace energy produced from fossil fuels and so contribute to achieve the target. Most on-farm biogas plants in Europe use slurry and co-substrate for biogas production. Farms, which are using dry manure chain technology, are excluded from the prevailing on-farm biogas technology. Dry anaerobic digestion biogas plants are used in communal organic waste disposal but scarcely on-farm although they show many advantages compared to anaerobic slurry digestion.

Previous research

This feasibility study takes up research findings of three locations: the research institute FAT Täänikon/Swiss, the research institute ATB Potsdam/Germany, and the university for applied sciences Weihenstephan-Triesdorf/Germany. One of the world’s first large scale dry anaerobic digestion biogas plant on-farm is under construction since 2002 in Järna/Sweden in the context of the European Regional Development Fund INTERREG II B project: Baltic Ecological Recycling Agriculture and Society (BERAS). This plant gives

an ideal opportunity to collect scientific data of energy and material flow of a dry anaerobic digestion biogas plant.

Objective

The feasibility study shall answer the following questions: Are there economical and ecological advantages of on-farm dry digestion biogas plants? How the construction and operation parameters of a dry digestion biogas plant influence environment, profit, and sustainability of on-farm biogas production? The hypothesis is that a dry digestion biogas plant integrated within a self-contained farm organism is in respect of economic and environmental criteria more competitive and more sustainable than an industrial biogas production unit of a mainstream farm based on slurry and co-substrate digestion. The aim of the feasibility study is to provide facts for decision makers in Finland to support the development of an economically and environmentally promising biogas technology on-farm. Further the results may encourage on-farm biogas plant manufacturers to develop and market dry anaerobic digestion technology as a complementary technology. This technology may be a competitive alternative for farms using a dry manure chain or for stockless farms. Finally the feasibility study offers young researchers of MTT Agricultural Engineering Research the unique opportunity to become familiar with biogas technology and biogas research and to establish international contacts for further career development.

Material and methods

First, we make a literature review about on-farm dry anaerobic digestion. Second, we set up a model that describes energy and material flow. Third, we collect data for the model particularly using brand new data available from the biogas plant in Järna. Cost and benefit analysis of biogas production and application is done using the collected data. Parameter variation is employed to find out the sensibility of the most important variables in terms of material and nutrient flow, sustainability, marginal profit, and interest yield of investment for the biogas plant.

Partners and their role

The co-ordinator of BERAS-project at the Biodynamic Research Institute Järna supervises the biogas plant construction and operation at Ytter Eneby farm. The site engineer and manager of the biogas plant of the Ytter Eneby farm is the contact person for the MTT staff. MTT staff does literature review, technical documentation, model calculations, and assessment. Recording data during visits at Järna is done in co-operation with experts from Järna. Experts of ATB Potsdam and State Institute of Farm Machinery and Farm Structures (ALB) in Stuttgart Hohenheim negotiate the research findings with MTT staff.

Time-table

The feasibility study starts from date of approval in spring 2004. Literature review, data collection, modelling, and technical documentation are completed 12 month later. The feasibility study as well as publications is completed 18 month after release of the project funds.

Dissemination and exploitation of results

The results are published in MTT's research working papers and professional journals. The results of the feasibility study are the bases for decision makers supporting the development of dry anaerobic biogas plants. Farmers, who consider establishing dry fermentation biogas plants, will receive in seminars and training workshops valuable figures to support decision-making. Small-scale entrepreneurs in the area of biogas technology and furnace manufacturers are offered a new business area with a bright future. For future development of dry anaerobic biogas technology on-farm a research and development project shall be launched in co-operation with farmers, manufacturers, scientists, and the funding agencies on the basis of the feasibility study results.

Background

European countries are committed to reduce CO_2 emission originating from fossil fuels. Additionally changes in policy priorities as well as the development of agricultural technology are important driving forces. The past subsidy policy urged farmers for mass production where yield maximisation and profit maximisation correlated closely. Now farmers are pushed to replace quantity by quality. The new challenge for pioneer farmers is therefore sustainable landscape management. This includes orienting farmers towards entrepreneurship and markets and responding to consumers and citizen's expectations to safeguard in the long-term integrity of farm support. (European Commission 2003). Both objectives sustainable landscape management and market oriented farming coincide with the basic organic farming principles (IFOAM 2002). Organic farming principles for their parts include the use of renewable energy resources and minimising nutrient losses on-farm as far as possible. On-farm produced biogas may replace energy produced from fossil fuels and so contribute to achieve the target to reduce green house gas emissions. Losses of nitrogen are reduced by dry anaerobic digestion of organic material.

Organic wastes are subject of environmental legislation and are no more allowed to be dumped from beginning of the year 2005 (VNp 861/1997). They are ideal co-substrates for biogas plants and support nutrient recycling on-farm. Animal based organic waste is also suitable for biogas production. In accordance with the EU-regulation (EU 1774/2002) animal by-products can be used for biogas production too. Anaerobic dry batch digestion reduces pathogen agents originating from humans, animals, and plants up to 99,9% (Look 1999, Brummeler 2000). In remote areas transport of animal based organic waste may easily increase transport costs unreasonably. Anaerobic digestion on-farm will relieve this burden.

Mainstream farm areas with intensive animal production like fur or poultry farms do not have enough farmland to dispose the manure according to the nitrate directive (VNA 931/2000). Especially fast growing animal production units need alternatives to usual manure and slurry treatment technology (Lehtimäki 1995). Dry anaerobic digestion may be a suitable technique to solve these problems. Most on-farm biogas plants in Europe use slurry and co-substrate for biogas production. But this technology is reasonable only on farms, where slurry technology is used already. Slurry based biogas plants are well developed in those European countries, where investment subsidies for biogas plants are granted in combination with high compensation for electric power production. These conditions prevail mainly in Germany. Farms, which are using a dry manure chain technology, or stockless farms are excluded from the prevailing on-farm biogas technology.

Dry anaerobic digestion biogas plants are used in municipal organic waste disposal (Chavez-Vazquez & Bagley 2002, Anonym 2002, Köttner & Kaiser 2001, Brummeler 2000, Look et al. 1999) but scarcely on-farm although they show many advantages.

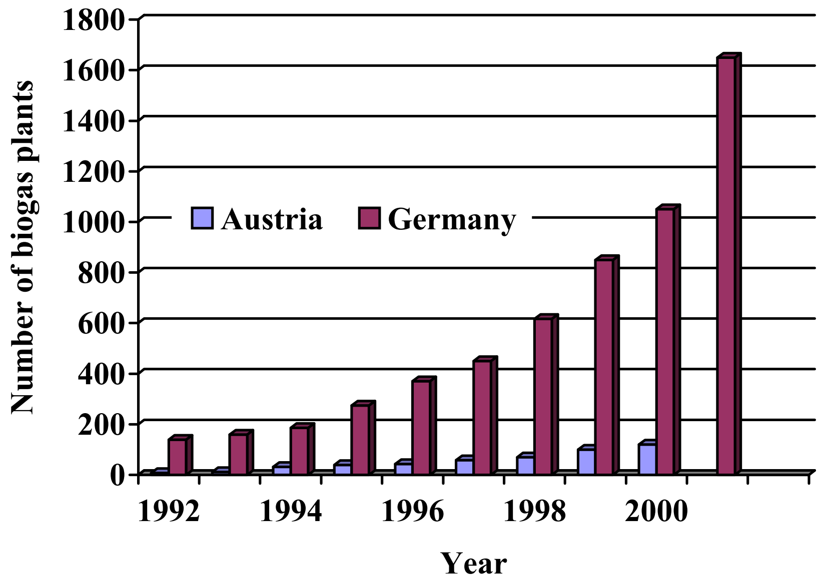

Figure 1: Number of biogas plants in Austria and Germany (Boxberger et al. 2002)

The top 10 benefits of dry anaerobic digestion biogas plants (Hoffmann & Lutz 2002) are obviously in line with the objectives of organic farming principles and strengthen sustainable agriculture:

1. Dry anaerobic digestion is suitable for nearly all farm residues like manure, plant residues, and household organic wastes. Higher energy density compared to slurry digestion requires less capacity of the reactor and reduces construction costs.
2. High dry matter content reduces transport costs due to reduced mass transfer in respect of the produced biogas quantity per mass unit.
3. Mobile digester modules allow batch production and continuous, well controllable gas production.
4. Dry anaerobic digestion residues are compostible and by this suitable fertilisers also outside the farm gate e.g. estate gardeners.
5. Dry anaerobic batch digestion does not need special techniques like slurry pumps, mixers, shredders, and liquid manure injectors for distribution. Most machinery necessary for filling and discharging the digester like front loader and manure spreader is often already available on-farm.
6. Process energy demand for heating is lower than in slurry reactors because of reduced reactor size. Process energy of dry anaerobic batch digestion is not required because continuous homogenisation is not needed.
7. Improved process stability and reliability. There occur no problems like foam or sedimentation. Possible digestion breakdowns are easily to resolve in batch digesters by exchanging the module.
8. Reduced odour emissions because there is no slurry involved. According to Benthem & Hänninen (2001) anaerobic digestion reduces odours from slurry and kitchen waste up to 80%.

9. Reduced nutrient run off during storage and distribution of digester residues because there is no liquid mass transfer.
10. Suitable for farms without slurry technology, especially farms using deep litter systems e.g. chicken production. 60% of Finnish manure originates from farms handling solid dung.

Previous research

Scientific research results about dry anaerobic digestion on-farm are scarcely available. In Finland there are no dry fermentation biogas plants and only some scientific publications about anaerobic digestion (Kuittinen et al. 2001, Salminen & Rintala 2001).

We know only about experiments in Täänikon/Swiss (Baserga et al., 1994), Triesdorf/Germany (Hoffmann 2001), and Potsdam/Germany (Linke 2002, Mumme 2003). There are some manufacturers of dry anaerobic digestion plants, but they set up prototypes or reference plants (Maierhofer & Wagner, 2002), which are not scientifically investigated. These plants consist usually of one or more reactors where the all stages (hydrolysis, acidification, methanization) of the digestion process proceed simultaneously.

One of the world's first large scale dry anaerobic digestion biogas plant on-farm is under construction since 2002 in Järna/Sweden in the context of the European Regional Development Fund INTERREG II B project: Baltic Ecological Recycling Agriculture and

Society (BERAS) (Granstedt 2003).

Figure 2: Two stage biogas plant of the Ytter Eneby farm, Järna. Photo: W. Schäfer

This project makes available data of energy, nutrient, and material flow of a two-stage dry anaerobic digestion biogas plant. The BERAS project co-ordinator Prof. Granstedt was working as research professor at the ecological research station of MTT and co-operated in the past decade with the Agricultural Engineering Research of MTT. He offers the unique opportunity for collecting data of the two-stage prototype dry anaerobic digestion biogas plant within a scientific scope.

Another prototype of a dry anaerobic digestion biogas plant is running under scientific control at Leibniz-Institute of Agricultural Engineering Bornim ATB (reg. Assoc.) in Potsdam/Germany within the key area 7 “Residual substance and wastewater treatment” research. “At the ATB various methods of producing biogas from liquid and solid residual substances are being developed and tested. In plants for liquid fermentation, additional substances such as fats are also being fermented to a growing extent. Overloading of the reactor due to these additives may trigger the inhibition of the methane-producing bacteria, which can lead to a breakdown in the biogas production. Early recognition of these critical stress conditions could substantially improve the efficiency of such plants. ATB scientists are examining the processes taking place in biogas plants with the aid of simple sensors and can thus make concrete recommendations to farmers and plant operators. Another new research approach covers the use of biogas in fuel cells, which ensures high current yields in smaller plants as well. This makes the new technology particularly interesting for farms” (http://www.atb-potsdam.de/Hauptseite-englisch/index2_e.htm).

Figure 3: Dry anaerobic biogas plant at ATB and laboratory of Dr. Linke. Photos W. Schäfer

Personal close contacts of MTT staff to ATB and Dr. Linke may support the evaluation of the data collected from the biogas plant in Järna.

Additionally Dr. Schäfer established contacts with the State Institute of Farm Machinery and Farm Structures (reg. Assoc.) located at the Institute 440 - Agricultural Engineering of the University of Hohenheim in Stuttgart. His contribution at the NKJ-conference in Turku (Schäfer 2003) based on the research of the director of ALB, Dr. Oechsner. Dr. Oechsner is in close co-operation with Dr. Linke at ATB and with the director Prof. Dr.-Ing. Peter Weiland of the Institute of Technology and Biosystems Engineering, Dept. of Technology of the Federal Agricultural Research Centre (FAL) within the scientific programme for the evaluation of biogas plants in the agricultural sector. “Within the scope of the triannual scientific program more than 60 agricultural biogas plants all over Germany are comparatively assessed concerning plant technology, efficiency, function and profitability. To take part in the examination, the plants have to be built in 1999 or later. This evaluation takes place with regard to the expected increasing use of biogas plants for the production of renewable energy. Based on this the capability of the biogas technology under different conditions is evaluated and its potential for further development will be shown."

Objective

The feasibility study shall answer the following questions: Are there economical and ecological advantages of on-farm dry digestion biogas plants? How the construction and operation parameters of a dry digestion on-farm biogas plant influence environment, profit, and sustainability of biogas production?

The hypothesis is that a dry digestion biogas plant integrated within a self-contained farm organism is in respect of economic and environmental criteria more competitive and more sustainable than an industrial biogas production unit of a mainstream farm based on slurry and co-substrate digestion.

The aim of the feasibility study is to provide facts and figures for decision makers in Finland to support the development of the economically and environmentally most promising biogas technology on-farm. The results may encourage on-farm biogas plant manufacturers to develop and market dry anaerobic digestion technology as a complementary technology. This technology may be a competitive alternative for farms using a dry manure chain or even for stockless farms.

Finally the feasibility study offers young researchers of MTT Agricultural Engineering Research the unique opportunity to become familiar with biogas technology and biogas research and to establish international contacts for further career development.

Material and methods

First we make a literature review about on-farm dry anaerobic digestion. Then we set up a model that describes energy, nutrient and material flow of the biogas plant in Järna and collect the input data for the model. Cost and benefit analysis of biogas production and application is done using the collected data. Parameter variation is employed to find out the sensibility of the most important variables in terms of material and nutrient flow, sustainability, marginal profit, and interest yield of investment for the biogas plant.

Literature review

Both MSc. Marja Lehto and MSc. Merja Paasonen are in charge for the literature review. The literature review contains the following issues:

Finnish legislation concerning dry anaerobic digestion, permissions and regulations of public authorities.

Equipment and its dimensioning at different locations like in animal housings and in joint use.

Raw material of plants, solid manure and other organic material (crop residues, organic waste, vegetable peeling residues, food industry waste and so on) as well as other waste originating from animal by products and their use in biogas production. Transport and storage of raw material, availability and sufficiency, net of suppliers, increase of energy density

Operating biogas plants, ease of operating, impact on work demand and employment, professionalism and training, work safety, reliability, self control, support measures for energy production, service, technical support and expert services.

Use of energy in different forms and possibility of use on countryside, heating, electric power production, green houses, dryers, and so on as well as gas storage issues.

Safe treatment and handling of digester residues, alternatives of treatment and exploitation, risk limits of poison materials and definition methods as well as hygienic requirements concerning nutrients, antibiotics, fodder additives, disinfectants.

Environmental impact of dry anaerobic digestion biogas plants, reduction of green house gases, use of nutrients and nutrient recycling, impact on water system.

Economic assessment in respect of Finnish farms. Modelling for economic assessment.

Use of end products in organic farming

Modelling

Dr. Schäfer is in charge to set up a model that describes energy, nutrient, and material flow of the biogas plant in Järna. The model described by Schäfer (2003) is extended for the requirements of the biogas plant in Järna. The input data for the model is collected at the site in Järna. This requires a technical documentation of the biogas plant. Dr. Schäfer does the documentation in co-operation with MSc. Lars Evers during Dr. Schafer's visits in Järna. The technical documentation embraces:

- Dimensions, capacity, technical specifications
- Material flow chart
- Process control logic

In Järna MSc. Lars Evers collects the following process data:

- Quantity of biogas produced by a gas meter.
- CO_2 content of the biogas produced in both reactors
- Electric power consumption for heating and operation

Samples from the site are taken by MSc. Marja Lehto and MSc. Merja Paasonen during visits at Järna to determine dry matter content and nutrient content of both fresh organic material and digestion residues in external laboratory. Cost and benefit analysis of biogas production and application is done using the collected data. Parameter variation is employed to find out the sensibility of the most important variables in terms of material and nutrient flow, sustainability, marginal profit, and interest yield of investment for the biogas plant. Dr. Schäfer does this work.

The results of the model calculation are compared with results from other dry anaerobic digestion plants. Evaluation of the results is done in close co-operation with the scientists from the Biodynamic Research Institute in Järna, the ATB in Potsdam and the State Institute of Farm Machinery and Farm Structures in Stuttgart Hohenheim.

Partners and their role

MTT/Agricultural Engineering Research

The unit of MTT/Agricultural Engineering Research carries out research and development on various applications of engineering in agriculture. The unit's aim is to study and develop sustainable and operational agricultural systems that produce high-quality products economically. The overall responsibility of the feasibility study is with Prof. Haapala, head of MTT Agricultural Engineering Research. He decides about travelling and the share of human and financial resources of the administrative, technical and public services of MTT Agricultural Engineering research related to the feasibility study.

MSc. Timo Mattila has the disciplinary responsibility over the Production Systems research team and the Buildings and Environment team at MTT Agricultural Engineering research and is supervising the feasibility study in respect of the timetable and the finances.

MSc. Antti Suokannas co-ordinates as team leader the research projects of the Production Systems team to which Dr. Schäfer belongs. The manager of the feasibility study and the contact person for the funding agency is Dr. Schäfer. He is in charge of the research work and responsible for the technical documentation and model calculations.

MSc. Maarit Puumala co-ordinates the research projects as team leader of the Buildings and Environment team to which MSc. Marja Lehto and MSc. Merja Paasonen belong. MSc. Marja Lehto and MSc. Merja Paasonen are in charge for the literature review and nutrient balance calculations.

The Biodynamic Research Institute Järna/Sweden

The aim of the Research Institute (http://www.jdb.se/sbfi/english/index.htm, Skilleby gård, S-153 91 JÄRNA, Sweden, sbfi@jdb.se) is to carry out scientific research focused on agriculture, environment and food quality.

The Biodynamic Research Institute was founded in 1986. Up until then it was part of "the Nordic Research Circle for Biodynamic Agriculture". Since the autumn of 1997 the Institute has been part of the Rudolf Steiner High School. The research activities at the Institute represent a continuation of the work that began in the early 1950's that has resulted in the development of alternative forms of agriculture.

Prof. Granstedt is the head of the institute and the co-ordinator of BERAS-project together with the assisting co-ordinator MSc. Leif Holmberg. The "Baltic Ecological Recycling Agriculture and Society (BERAS)" project (http://www.jdb.se/beras/) is a European Regional Development Fund INTERREG III B project: Case studies, complemented with scenarios and consequence analyses, of ongoing practical, local ecological initiatives to promote local food supply cooperation between consumers and ecological producers (organic farmers, local food processors and distributors) in rural villages in the countries around the Baltic Sea, with the aim of learning and promoting more sustainable food supply systems and lifestyles. Time 2003-2006. Total budget 2.156.000 EURO.

Embedded into the BERAS-project is the project "Energy self-reliance at the farm level". Models for calculating energy balances have been drawn up. The project is in co-operation with JTI and similar initiatives at other locations, especially with Öknaskolan and Nynäs Gård in the Sörmland region, where a facility is already established. The aim is to show how a decreased use of fossil fuel is possible within the food sector. Co-operation will take place with similar initatives on other farms. Finance: The costs have been calculated to 2,5 million SEK and 50% State contribution of the investment costs has been granted.

The aim of the facility is to increase knowledge and demonstrate different ways of better renewable energy usage at the local level. It is important to get the economic means to develop, document and disseminate the knowledge gained from this project.

Since 2002 a biogas plant prototype is under construction at Ytter Eneby farm in Järna. MSc. Lars Evers is site engineer and manager of the biogas plant. He is the contact person for the MTT staff.

Leibniz-Institute of Agricultural Engineering Bornim ATB

The ATB's (Leibniz-Institute of Agricultural Engineering Bornim (reg. Assoc.), Max-Eyth-Allee 100, D-14469 Potsdam, Tel.: +49 (0)33156990, Telefax: +49 (0)331549630, atb@atb-potsdam.de) task is to create process-engineering bases for sustainable land-use management and to provide innovative technical solutions for industry. By combining scientific and engineering findings, especially in the field of new technologies such as biotechnology and information technology, with economic and social science expertise, ATB aims to ensure that the newly developed processes and technical solutions are profitable for both manufacturers and users, at the same time ensuring environmental protection and sustainability.

The head of the department "Bioengineering" is PD Dr. sc. agr. Dipl.-Ing. Bernd Linke. His colleague Dr.-Ing. Volkhard Scholz is expert in bio energy issues within the department "Post Harvest Technology". Both experts are ready for co-operation for the evaluation of the research findings.

State Institute of Farm Machinery and Farm Structures

The State Institute of Farm Machinery and Farm Structures (reg. Assoc.) (Garbenstraße 9, D-70599 Stuttgart, (++49)0711/459-2683, E-mail la740@uni-hohenheim.de, http://www.uni-hohenheim.de/i3ve/00000700/00390041.htm) is integrated into the Institute 440 - Agricultural Engineering of the University of Hohenheim in Stuttgart together with „Arbeitsgemeinschaft Landtechnik und Ländliches Bauwesen Baden-Württemberg (ALB) e.V. (http://www.uni-hohenheim.de/i3ve/00000700/00522041.htm). Dr. Hans Oechsner is researcher at the State Institute of Farm Machinery and Farm Structures and director of the ATB. Since many years he is involved in biogas plant research and he is ready for co-operation for the evaluation of the research findings.

Time-table

The feasibility study starts from date of approval in spring 2004. Literature review, data collection, modelling, and technical documentation are completed 12 month later. The feasibility study as well as publications is completed 18 month after first release of the project funds.

	Task	mm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Literature review																			
1.1	Legislation	1,0																		
1.2	Publications	3,3																		
2	at Ytter Eneby in Järna																			
2.1	Control and operating	3,8																		
2.2	Measuring quantity of biogas	0,3																		
2.3	Measuring CO2 content of biogas	0,2																		
2.4	Measuring electric power consumption	0,2																		
3	Technical documentation																			
3.1	Collecting data on site	0,6																		
3.2	Sampling manure and fermentation residues, laboratory analysis	1,2																		
3.3	technical specifications	1,0																		
3.4	Material flow chart	0,5																		
3.5	Process control logic	0,5																		
4	Modelling and calculation																			
4.1	Material flow	0,5																		
4.2	Energy flow	0,5																		
4.3	Material flow	0,5																		
4.4	Calculation model	3,0																		
5	Publications and seminars																			
5.1	Publications	3,5																		
5.2	Seminars	0,5																		
6	Project management and co-ordination																			
6.1	Co-ordination, supervision	0,2																		
6.2	Evaluation with experts from Potsdam and Stuttgart	0,2																		
		21,5																		

Dissemination and exploitation of results

The results of the feasibility study are the bases for decision makers supporting the development of dry anaerobic biogas plants. Farmers like Kylämäen Hevostila http://www.unki.net/index.htm (Juha Kylämäki, Hallintie 31, 21490 MARTTILA, p. (02) 4845 800, E-mail kylamaki@marttila.fi), who consider establishing dry fermentation biogas plants, will receive in seminars and training workshops valuable figures to support decision-making. The results are published in MTT's research working papers and professional journals

Enterprises like EcoDream Oy http://akseli.tekes.fi/Resource.phx/enyr/streams/en/preseco-en.htx (Mikko Kantero, Mikko.Kantero@ekodream.fi), Rumen Oy http://www.rumen.fi/, (Rauhankatu 11 B, 15110 Lahti, +358 3 871850, rumen@rumen.fi), and Vapo Oy Biotech http://www.vapo.fi/, (Yrjönkatu 42, 40100 Jyväskylä, puh. (014) 623 623) showed interest in on-farm biogas production systems. Also other small-scale entrepreneurs like furnace manufacturers are invited to the seminars to explore a new business area with a bright future. For future development of dry anaerobic biogas technology on-farm a research and development project shall be launched in co-operation with farmers, manufacturers, scientists, and the funding agencies on the basis of the feasibility study results and its seminars.

Advisory group / Steering Committee

Proposal for steering committee: Pirjo Salminen, Representative of Ministry of Agriculture and Forestry; prof. John Sumelius, HY; NN, Pro Agria, Vantaa; Erkki Kalmari, Metener Oy, Jyväskylä.

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Bilaga 3

Anaerobe Vergärung von Festmist – eine neue Technologie zu Schließung des Nährstoff- und Energiekreislaufes auf dem landwirtschaftlichen Betrieb

Anaerobic digestion of manure – a new technology to close the nutrient and energy circuit on-farm

W. Schäfer[1], L. Evers[2], M. Lehto[1], S. Sorvala[1], F. Teye[1] und A. Granstedt[2]

Key words: biogas, compost, renewable energy, anaerobic digestion

Schlüsselwörter: Biogas, Kompost, erneuerbare Energie, anaerob, Vergärung

Abstract:
The Biodynamic Research Institute in Järna developed at the farm Yttereneby a two phase biogas plant. The plant digests manure of dairy cattle and organic residues originating from the farm and the surrounding food processing units. A new technology for continuously filling and discharging the biogas reactor was developed and implemented. The biogas is used to produce heat for farm buildings and in future to fuel farm machinery and vehicles. Digestion residues are separated into a solid fraction for composting and into a slurry fraction. This paper presents first results of the technical documentation and preliminary results concerning biogas production, mass- and nutrient balance.

Einleitung und Zielsetzung:
Biogasanlagen eignen sich hervorragend um den Nährstoffkreislauf und den Energiekreislauf eines landwirtschaftlichen Betriebes zu schließen. Die derzeit marktgängigen Biogasanlagen arbeiten fast ausschließlich mit Flüssigmist und Kosubstraten. Betriebe, die eine Festmistkette benutzen, wie bei der Rinder-, Pferde- und Geflügelhaltung üblich, sind daher in der Regel von der marktgängigen Technologie ausgeschlossen, bzw. haben einen entscheidenden Wettbewerbsnachteil. Biodynamische Betriebe legen besonderen Wert auf Mistkompost.

Die Vergärung organischen Materials mit 15-50% TS (fälschlich auch Trockenvergärung genannt) auf dem landwirtschaftlichen Betrieb ist derzeit wieder Gegenstand intensiver Forschung (Linke 2004). Dazu wurden Prototypreaktoren verwendet, die jedoch nur selten zu marktfähigen Produkten reiften. Technische Dokumentationen, die einen Nachbau erlauben, sind uns nicht bekannt. Uns ist nur ein Hersteller bekannt, der eine einstufige Anlage für die absätzige Vergärung von stapelbarem organischen Material liefert. Dessen Angaben über die Funktion und Leistungsfähigkeit dieser Anlage sind bislang wissenschaftlich nicht bestätigt. In diesem Beitrag sollen ein Prototyp eines zweiphasigen Biogasreaktors zur kontinuierlichen Vergärung von Festmist und organischen Abfällen auf einem Demeterbetrieb und erste Messergebnisse vorgestellt werden.

Methoden:
Eine technische Dokumentation wurde nach der Europäischen Norm für Fließschemata für verfahrenstechnische Anlagen Regeln (EN-ISO 10628:1997) erstellt. Eine vereinfachte Darstellung des Materialflusses der Anlage zeigt Abb. 1. Kot, Stroh und Haferspelzen aus einem Milchviehanbindestall mit 55 GV werden mit dem Faltschieber in den Zuführkanal vor dem Hydrolysereaktor geschoben und von dort mit einem weiteren hydraulisch betätigten Faltschieber durch ein 400 mm PVC-Rohr in den oberen Teil des 30° geneigten Hydrolysereaktors gepresst. Infolge der Schwerkraft ver-

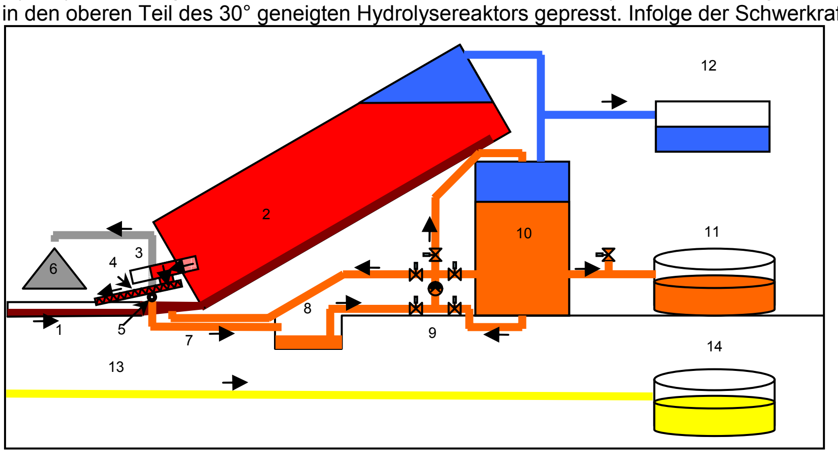

Abb. 1: Materialfluss der Biogasanlage in Yttereneby, Järna, Schweden. 1 Zuführkanal des Frischmistes, 2 Hydrolysereaktor, 3 Schublade zum Entleeren, 4 Schnecke zum entleeren der Schublade, 5 Schneckenpresse zum Trennen der festen und flüssigen Fraktion, 6 Feste Fraktion nach der Hydrolyse, 7 Abflussrohr der flüssigen Fraktion, 8 Zwischenlager der flüssigen Fraktion, 9 Pumpe und Steuerventile, 10 Methanreaktor, 11 Lager des flüssigen Faulsubstrats, 12 Gaslager, 13 Harnabflussrohr, 14 Harnlager

mischt sich das neu zugeführte Substrat mit dem bereits Vorhandenen und sinkt nach unten. Nach einer hydraulischen Verweilzeit von 26 Tagen bei 38°C wird das Gärsubstrat von einer Schublade ohne Boden aus dem Reaktor entnommen. Die Schublade wird in einem rechteckigen Kanal geführt und über einen Hydraulikzylinder bewegt. Bei jedem Entladezyklus fallen ca. 100 l Gärsubstrat in die darunterliegende Transportschnecke. Schwerkraftbedingt fällt ein Teil des Gärsubstrates in die quer darunter liegende Schneckenpresse, der andere Teil wird in den Zuführkanal entleert und mit dem Frischmist vermischt. Die feste Fraktion des Gärsubstrates aus der Schneckenpresse wird auf der Dungplatte des Betriebes gelagert und kompostiert, die flüssige Fraktion gelangt über einen Zwischenspeicher in den Methanreaktor. Ein Teil der flüssigen Fraktion wird in den Presskanal zurückgeführt um Verstopfungen vorzubeugen. Nach einer hydraulischen Verweilzeit von 16 Tagen bei 38°C wird das Faulsubstrat aus dem Methanreaktor in einen Lagerbehälter mit Schwimmdecke gepumpt. Das in beiden Reaktoren entstehende Biogas wird in einem Sack gespeichert, bevor es verbrannt wird. Der Urin wird bereits im Stall über die perforierten Kanäle der Faltschieberanlage vom Mist getrennt und in einem separaten Behälter mit Schwimdecke gelagert.

Proben des organischen Materials wurden vom Frischmist im Zuführkanal 1, vom Gärsubstrat der festen Fraktion 6 und vom flüssigen Faulsubstrat nach der Methanvergärung 11 entnommen. Die erste Probenahme erfolgte am 3.3.04 und wurde im Labor HS Miljölab AB in Kalmar, Schweden auf Stickstoff- und Phosphorgehalt und Trockensubstanz analysiert. Masse und Trockensubstanz des in 24 h zugeführten Frischmistes und der dem Hydrolysereaktor entnommenen festen Fraktion des Gärsubstrates wurden ermittelt. Die zweite Probenahme erfolgte am 6.5.04 und wurde im Labor Novalab Oy in Karkkila, Finnland auf Stickstoff-, Phosphor-, Kaliumgehalt und Trockensubstanz analysiert. Die in 24 h eingestreute Masse an Stroh und Haferspelzen wurde gewogen. Masse und Trockensubstanz des Kotes wurden aus dem Frischmist abzüglich Stroh- und Haferspelzmasse berechnet. Die organische Trockensubstanz des Frischmistes, der Haferspelzen und des Strohs wurden durch 3-stündiges Erhitzen auf 550°C ermittelt. Der Gasertrag wurde für beide Reaktoren über je eine gebrauchte Stadtgasuhr gemessen und der Zählerstand wurde täglich abgelesen. Der CO_2-Gehalt wurde im Glaskolben durch Ausfällen von Natriumkarbonat mit Natronlauge ermittelt. Der Wasserdampfgehalt im Biogas wurde mit einem geschätzten Mittelwert von 3 Vol-% des Biogases (Weiland, 2003), angenommen. Die Berechnung der Biogasmasse erfolgte mit CO_2: 1,85 kg m^{-3}, CH_4: 0,67 kg m^{-3}, Wasserdampf: 0,752 kg m^{-3}, gültig für 0°C und 1 bar Luftdruck. Auf die Umrechnung des Gasertrages auf Normkubikmeter wurde wegen der mangelhaften Messgenauigkeit verzichtet. Im Kompostierungsversuch (10.5.-13.8.04) wurden 50 l Frischmist sowie 50 l der festen Fraktion des Gärsubstrates bei 15°C in der Klimakammer des Agrartechnikinstitutes kompostiert. Danach wurden die Nährstoffgehalte im Labor Novalab Oy in Karkkila, Finnland auf Stickstoff, Phosphor-, Kaliumgehalt und Trockensubstanz analysiert.

Ergebnisse und Diskussion:
Die Anlage wurde Mitte November 2003 in Betrieb genommen. Der Biogasertrag von der Inbetriebnahme bis zu Beginn des Weidegangs ist in Abb. 2 dargestellt. Der Produktionsabfall Anfang Januar wurde durch eine eingefrorene Gasleitung verursacht, der Produktionsabfall im April durch ein Leck in der Gasleitung. Im Mittel ergab sich ein Ertrag von 129 l Biogas je kg oTS, was bei ca. 65% Methangehalt 84 l Methan oder einem Heizwert von ca. 0,84 kWh kg^{-1} oTS entspricht. Am 29.3.04 erreichte die Anlage mit 262 l kg^{-1} oTS den Höchstwert.

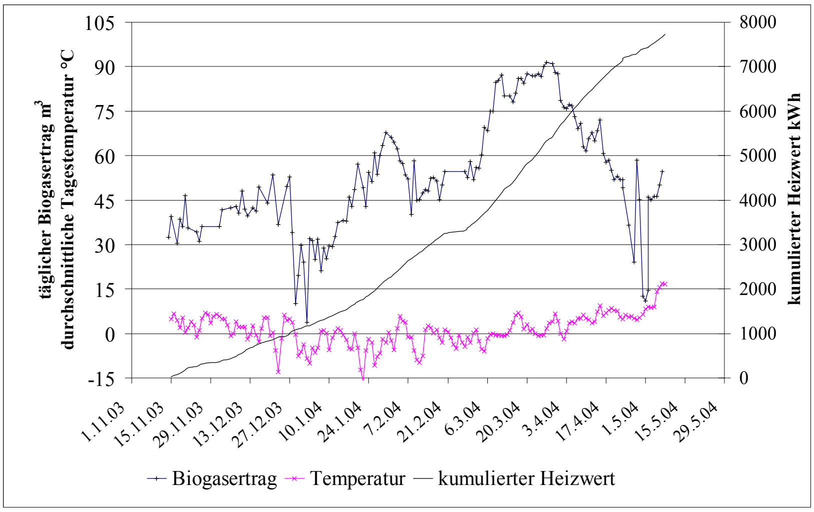

Abb 2: Kumulierter Heizwert, Biogasertrag und durchschnittliche Tagestemperatur der zweiphasigen Biogasanlage in Yttereneby zwischen dem 15.11.2003 und 8.5.2004

Die Massenbilanz ergibt, dass über 69% der zugeführten oTS aus Stroh und Haferspelz stammt und ca. 48% der oTS nach der Vergärung zur Kompostierung des festen

Gärsubstrates zur Verfügung steht. Die Stickstoffbilanz zeigt, dass nach der anaeroben Vergärung deutlich mehr löslicher Stickstoff und Gesamtstickstoff als bei der aeroben Vergärung zur Verfügung steht. Die Ergebnisse sind statistisch nicht abgesichert, da bislang nur Mittelwerte aus zwei Messtagen zur Verfügung stehen.

Tab 1: Massen- und Nährstoffbilanz anaerober und aerober Vergärung. FM Frischmasse, oTS organische Trockensubstanz, N_{org} organischer Stickstoff, $N_{lös}$ löslicher Stickstoff, N_{tot} Gesamtstickstoff.

	FM	*oTS*	*N_{org}*	*$N_{lös}$*	*N_{tot}*	*NH_4*	*NO_3, NO_2*	*K*	*P*
	kg d^{-1}	*kg d^{-1}*	*kg d^{-1}*	*kg d^{-1}*	*kg d^{-1}*	*kg d^{-1}*	*kg d^{-1}*	*kg d^{-1}*	*kg d^{-1}*
Anaerobe Vergärung von 2000 kg d^{-1} Stallmist									
Kot	1718	107,8			8,29			6,06	2,06
Stroh	26	24,1			0,15			0,61	0,04
Haferspelz	256	216,7	0,55		0,56		0,02	1,13	0,16
Summe Input	**2000**	**348,6**	**7,36**	**1,64**	**9,00**	**1,34**	**0,242**	**7,8**	**2,25**
Gärsubstrat, feste Fraktion	769	167,2	2,75	0,59	3,34	0,54	0,04	2,38	0,64
Faulsubstrat	1175	44,7	2,47	1,65	4,34	1,41	0,24	4,00	0,93
CO_2	34,0								
CH_4	20,8								
Wasserdampf	1,15								
Summe Output	**2000**	**211,9**	**5,22**	**2,24**	**7,90**	**1,95**	**0,28**	**6,38**	**1,57**
Kompost der festen Fraktion	313	73,2	1,94	0,04	1,97	0,02	0,02	2,26	0,50
Kompost und Faulsubstrat	**1487**	**117,9**	**4,40**	**1,68**	**6,53**	**1,43**	**0,25**	**6,25**	**1,43**
Verluste	513	230,7	2,96		2,47			1,55	0,82
Aerobe Vergärung von 2000 kg d^{-1} Stallmist									
Kompost	**872**	**159,8**	**4,50**	**0,11**	**4,62**	**0,05**	**0,06**	**5,93**	**1,74**
Verluste	1128	188,8	2,86	1,53	4,38	1,29	0,18	1,87	0,51

Schlussfolgerungen:
Die Biogasanlage in Järna eignet sich zur kontinuierlichen Vergärung von Festmist und organischen Abfällen und trägt wesentlich zur Schließung des betrieblichen Energie- und Nährstoffkreislaufes bei. Zur Absicherung der Ergebnisse sind weitere Messungen nötig. Der bislang gemessene Biogasertrag liegt unter den möglichen Erträgen, wie ein Vergleich mit jüngsten Forschungsergebnissen zeigt (Schattner et al, 2000, Mumme 2003, Møller et al, 2004). Eine Optimierung der Anlage hinsichtlich Raumbelastung und hydraulischer Verweilzeit dürfte zu wesentlich höheren Gaserträgen führen, erfordert aber eine verbesserte Messtechnik. Danach ist eine ökonomische Bewertung erforderlich, um die Wettbewerbsfähigkeit dieser neuen Technologie beurteilen zu können.

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