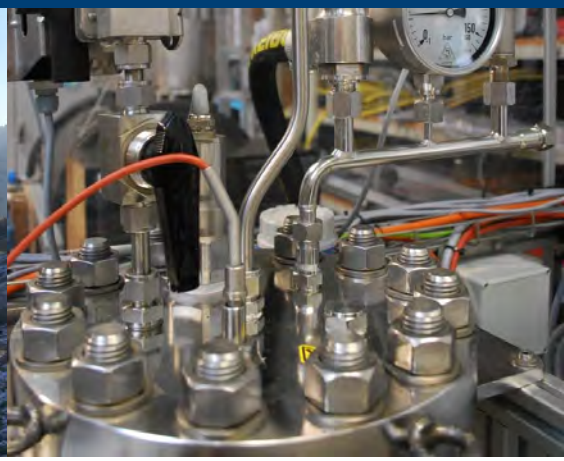
UNIVERSITY OF HOHENHEIM

200 YEARS 1818 2018

Annual Report 2017

State Institute of Agricultural Engineering and Bioenergy



University of Hohenheim
State Institute of Agricultural Engineering and Bioenergy (740)

LANDESANSTALT für Agrartechnik & Bioenergie

The State Institute of Agricultural Engineering & Bioenergy

The State Institute of Agricultural Engineering and Bioenergy is a special institution of the University of Hohenheim and has the following duties to fulfill:

- Practical research
- Special consulting for the Baden-Württemberg agriculture
- Technical advice for agricultural and industrial companies
- Training of the agricultural management teaching and consulting staff in relation to the state of the art and new test results

Since the State Institute has been devoting itself for many years to special topics such as biogas production and bioeconomy issues, the range of tasks mentioned has expanded significantly in recent years. The participation in the teaching of biogas in collaboration with Prof. Thomas Jungbluth and Prof. Joachim Müller has become an integral part of the curricula for students of renewable raw materials and bioenergy courses and agricultural sciences. Students prepare their Bachelor's and Master's theses within the framework of research projects and gain valuable experience working as scientific assistants at the State Institute.

The year 2017 was a particularly active year for the State Institute. It was marked by a series of national and international events. A particular highlight was the international conference "Progress in Biogas IV", which took place from 8 to 10 March at the University of Hohenheim together with the IBBK. The three parallel session event offered space for a total of 73 lectures, 17 short lectures and about 60 posters. The additional showroom for companies provided an opportunity for discussion with the manufacturers of measuring technology up to complete biogas plants. On the third day of the event, the participants were offered four practical workshops on topics such as hygiene, nitrogen-rich substrates, measurement technology, process stability and mechanical processing technology. More than 300 participants from 32 countries took part in the congress. In conjunction with this congress, a special issue has been prepared in the scientific journal Bioresource Technology (BITE). It included a total of six contributions by researchers from the State Institute. Prior to the Progress in Biogas IV conference, the "Great Cycle Meeting" took place in Hohenheim. At this meeting of the Chinese Agricultural University of Peking (CAU) and Hohenheim, in which guests from different countries participated, discussions were held on the recycling processes in the agricultural utilization of organic substances and solutions were sought. Two events for the German-speaking area: "Biogas Infotage, Ulm" and the "Hohenheimer Biogastag", where the State Institute is co-organizer, made it possible to directly transfer new insights to practice.

The State Institute is responsible for the scientific supervision of the research biogas plant at the experimental station Lindenhöfe. It was urgently necessary to replace the old digestate storage tank from the 1960s with a modern tank with leak detection and gas-tight roof design. This will provide additional safety and a significant improvement in the environmental impact of the biogas plant. The storage of the digestate is now possible for up to 9 months. In addition, the entire slurry pumping technology will be renewed and a test stand for separators will be set up. Thus, the nutrients can be used more efficiently than before and protect the environment. From the gas-tight closed area, no gases can escape. The large gas space (1,800 m^3) allows the interim storage of the resulting biogas and its subsequent, targeted utilization in combined heat and power plant (CHP). The renewal of the substrate introduction technique greatly enhances the operational flexibility. Electricity can now be generated more flexibly and adapted to the needs of the experimental station. For the supervision of the rebuilding of the storage container and the commissioning Dr. Lemmer and Dr. Nägele are responsible.

It has also been possible to raise funds for improved laboratory equipment in Hohenheim. The long-planned and now optimally equipped biogas laboratory for methane yield tests was commissioned in the summer of 2017. The additional procurement of a cryothermostat incubator allows the emission potential of practical biogas plants to be precisely determined. There are now more than 750 small fermenters available for HBT testing, allowing a parallel study of 250 substrates. Another 2-channel micro GC facilitates the determination of the composition of biogas. A

potentiostat enables exact investigations in the field of MFC (Microbial Fuel Cell). An ICP-MS device with associated sample preparation technology complements the previously missing measurement option for the analysis of elements, e.g. of micronutrients in the biogas process. Here are also two muffle furnaces to mention, which replaced old equipment. I thank both the Rectorate and the BMBF for the extensive financial support in the procurement of these important large appliances!

Biogas has been receiving great interest in Germany for more than 20 years. Due to the legal regulations of the EEG, biogas production has become an important pillar of many agricultural businesses. Today, there are more than 9000 agricultural biogas plants, where biogas is predominantly converted into electricity and heat via CHP. In addition, biomethane will be produced at about 200 large plants and fed into the natural gas grid. About 6 - 7% of German electricity consumption currently comes from biogas. The State Institute has made a significant contribution to this highly positive development through research and consulting, and the identification of economic and professional boundaries. In the recent political decision to restrict the support of biogas in the future via the EEG, it was not considered that an important and excellent source of renewable energy will gradually disappear after 20 years of operation. A continuous reduction of production costs per kWh biogas stream, as originally planned, could not be achieved so far, because the quite reasonable conditions for the construction and operation of the digesters (leakage detection, safety requirements, maintenance and control expenses, housing, ...) were regularly increased and thus the investment costs have more than doubled in the last 15 years. At the same time, however, the technical reliability, flexibility and safety of the systems improved considerably.

The legal changes require further research to prevent a rapid loss of technology after the expiration of the 20-year EEG term. The State Institute has participated in three new research projects within the framework of the "Post-EEG call". Perspectives for existing biogas operations should be identified and verified in feasibility studies in order to continue to enable economic production of this outstanding "green electricity" and to ensure added value for the farms in Baden-Württemberg.

Due to the increased international commitment of the State Institute, new research approaches for the exploitation of previously unexploited potentials, e.g. in tropical countries. Here, for example, thought of by-products of fruit and food production. This international activity is an excellent complement to regional research activities and paves the way for German biogas companies to open up new markets.

The very dedicated and highly motivated team of the State Institute willingly faces new challenges and tries to strengthen the situation of agricultural companies and biogas plant operators. We look forward to receiving any suggestions and are open for a partnership-based cooperation with research and industry partners in Germany and worldwide.

Dr. Hans Oechsner
Head of the State Institute

Change of senior director of the state institute

According to the statute of the state institute, the senior director has the task of coordinating the work of the state institute with the work of the university and in particular with the institute of agricultural engineering. In addition, he represents the affairs of the state institute in the committees of the university to which he belongs. This task was taken over by Professor Jungbluth in March 1992. The focal point of the then State Institute of Agricultural Machinery and Construction was already at this time the topic of renewable energy. Particularly large-scale projects dealt with the use of cold-pressed vegetable oil in special, adapted diesel engines for tractors. Added to this was the harvesting and processing of flax and the thermal utilization of renewable raw materials. The research field of biogas production, which was initially small in the 1990s, was increasingly becoming more important and economically powerful due to the continuously increasing interest of farmers.

In the following years, the focus on biogas was further expanded. Laboratories were modernized, partly automated, and new measuring equipment could be procured. The development of measurement methods has been worked on, for example, the VDI Guideline 4630 are groundbreaking. The state institute developed under its current director, Dr. Oechsner, and his deputy, Dr. Lemmer, into one of the leading research institutions in the field of biogas. As an important instrument for this, the research biogas plant at the Unterer Lindenhof was created in 2008 with great support from the university management. This was able to generate part of the energy for the experimental station and served more and more for demonstration and for the education of the students. During the time of construction of the research biogas plant, the Federal Ministry of Food and Rural Development set up a "Bioenergy Research Platform" as part of the Baden-Württemberg Future Offensive IV. The topic "Renewable Energy" focuses on biogas in a network of the most important and most notable research institutes in the state developed and coordinated by the state institute.

This practice-oriented research is the original statutory mission of the state institute. Increasingly, however, it became clear that future-oriented tasks, especially in connection with the further development of biogas technology, will not be possible without the extension to fundamental research. Examples include innovative high-pressure methanation, hydrogen methanation as an element of power-to-gas technology and cascade use of the substrates, with the aim of adding further value to farms by generating platform chemicals. This new task is reflected, on the one hand, in the large increase in the number of doctoral students working on projects at the State Institute, but also in the number of scientific publications. This scientific achievement ensures the state institute a high position in the international scientific community and within the University of Hohenheim.

In addition to the training of doctoral students, the employees of the state institute also contribute their extensive knowledge to teaching at the Faculty of Agricultural Sciences. They make significant contributions to the study programs General Agricultural Sciences, specializing in Agricultural Engineering, Bachelor and Master programs Renewable Resources and Bioenergy. In addition, both the practical as well as the basic projects provide excellent opportunities for students to do their thesis in a future-oriented topic.

With the departure of Prof. Thomas Jungbluth from active service, the senior director of the State Institute is transferring to Professor Joachim Müller of the Institute of Agricultural Engineering with effect from April 01, 2018. Prof. Joachim Müller has also been active in the field of renewable energies for many years, which should enable new synergies.

Biogas Measurement Program III - Factors for the efficient operation of biogas plants (BMP III)

The construction of new plants has been significantly reduced in recent years due to changes in the Renewable Energy Sources Act (EEG). At the same time, the end of the 20-year-long remuneration under the EEG 2004 and 2009 threatens to lead to a decommissioning of old plants. This situation has changed the biogas sector in Germany. An improvement in efficiency and thus profitability as well as a sensible re-design of bonuses in the EEG are urgently necessary to maintain the number of plants and the market leader in biogas in Germany.

In Biogas Measurement Program III, biogas plant operators and politicians are being developed with the help of a monitoring system for 60 biogas plants throughout Germany. A complete picture of the plant stock and current practice is presented as well as an evaluation of new measurement methods for the exact determination of the efficiency of biogas plants. This is intended to show both efficient plant concepts and difficulties in the operation of biogas plants.

An economic, biological and technical analysis of the plants is prepared to determine the efficiency. For biological analysis, samples are taken from all containers and substrates on a monthly basis, and they are analyzed for a variety of parameters. All other analyses are based on operating data. In order to record these, operating daybooks as well as available meter readings are recorded and read.

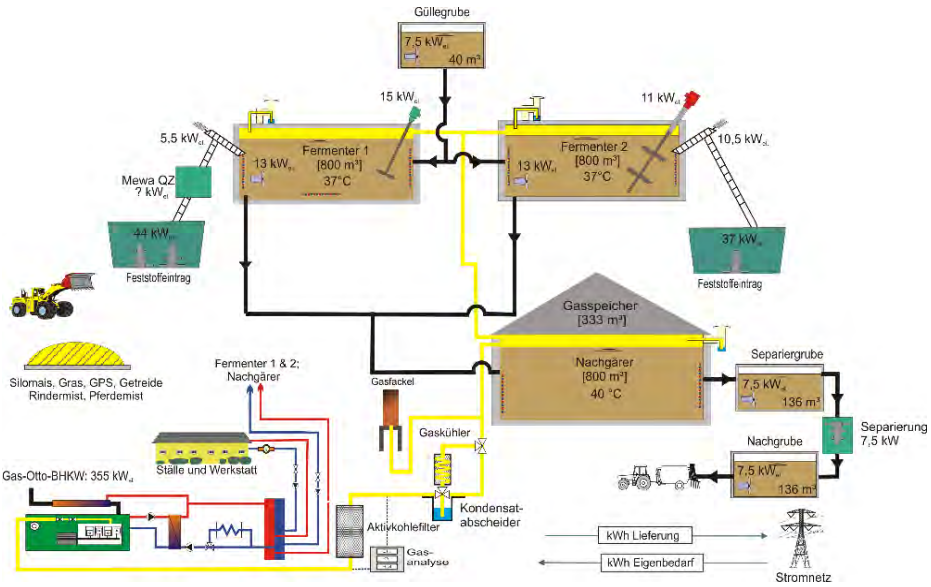
A comparison of theoretical data calculated from the results of the biological analysis and the operating data is used to validate the measurement results. At the same time, the comparison is used as the basis for the doctorate awarded in BMP III. In the doctoral dissertation, the deviations of the data from one another are examined and the causes examined in more detail.

M. Sc. Benedikt Hülsemann

M. Sc. Lijun Zhou

Dr. Hans-Joachim Nägele

Dr. Hans Oechsner



Scheme of the Unterer Lindenhof facility investigated under BMP III

Funding:
Fachagentur für Nachwachsende Rohstoffe e.V.

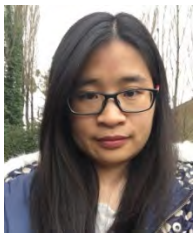
Partners:
Deutsches Biomasse Forschungszentrum (DBFZ)

Bayerische Landesanstalt für Landwirtschaft (LfL)

Kompetenzzentrum Erneuerbare Energien und Klimaschutz Schleswig Holstein (EEK.SH)

Project duration:
Jan. 2016 – Dec. 2018

German Biogas Measurement Program III – A Suitable Program for China? Biogas Plant Operation and Performance Assessment (CBMP)



M. Sc. Lijun Zhou

M. Sc. Benedikt Hülsemann

Dr. Hans-Joachim Nägele

Dr. Hans Oechsner

Dr. Guo Jianbin (CAU, Peking)

China's agro-industries create billions of tons of biomass waste annually, which can potentially be used to produce energy. According to the country's 13th Five-Year Plan (2016-2020), China will allocate CNY 50 billion ($7.3 billion) to build biogas projects on rural areas to boost its clean energy use, which will include construction of 172 new biogas projects and 3,150 large-scale biomethane projects. However, given the current development status quo, obstacles in biogas sector, such as low plant operation efficiency and low biogas production efficiency, lack of standards and insufficient policies have emerged.

The research will be drawn from lessons learnt from the previous two German Biogas Mesurement Programs (BMP) and the on-going BMP III. Furthermore, BMP III methodology will be applied and adjusted in China, to establish the first Chinese BMP as appropriate. The first trail round of Chinese Biogas Measurement Program (CBMP) started in mid October 2017 at three politing biogas plants in Beijing, China. Such plants were selected due to the application of different substrates, plant scale (medium and large scale) and long operation history (min. 10 years). In align with the German BMP III, during the measurement, samples, i.e., substrates, feeding slurry, fermentation slurry, digestate, biogas were collected and lab measurements of key indicators, i.e., biogas potential of different substrates through HBT, features of samples (TS/oTS, FOS/TAC, NH_4-N, PO_4^{3-}-P, biogas quality, etc.) were measured. Furthermore, the methodology was adjusted to reflect the situation and different legislations.

In terms of policy, studies related to the government policy in countries with more advanced biogas technologies and market, for instance, Germany, Sweden and Denmark, will be carried out, to present a complete and clear picture to the Chinese government about how other governments are developing and supporting the sector. In addition, economic analysis will be carried out to all studied biogas plants to assess the viability. Analysis for the annual major income, expenses and balance will be carried out, comparisons for the different financial status by the application of the PRC domestic air pollution control policies will be conducted especially. This will draw a picture of how to make the biogas plant operation more profitable in the market, rather than only rely on the government subsidies. The analysis results will also provide the government a picture of how the policy shall be structured appropriately.

Partner:
China Agriculture University, The People's Republic of China

Project duration:
Nov. 2016 – June 2019

The three plants of the Chinese biogas measurement program (October 2017)

Flexible feeding in biogas processes with model-based process detection in full-scale (FlexFeed)

M. Sc. Philipp Kress

Dr. Hans-Joachim Nägele

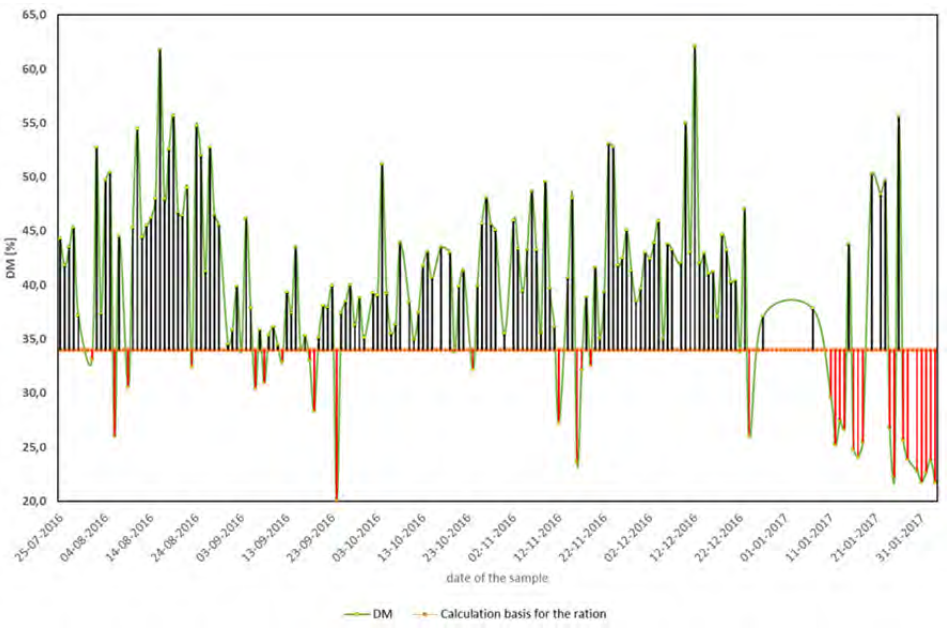
Dr. Hans Oechsner

Due to a decrease in farming area, the availability of raw materials as well as the current political conditions, biogas producers are using measuring techniques to either increase process efficiency or provide an alternative income. Biogas plants have the potential to secure the supply and stability by increasing dynamics in the power grid. As the gas upgrading processes are not profitable for many existing biogas plants, current attemps try to increase the flexibility of power production chiefly expanding gas storage and the co-generation unit.

With the help of storable biomass, it is possible to operate the digester in a controllable and flexible manner through optimized feeding management techniques. The impacts of the widely varying feeding management techniques on the biological, rheological process engineering parameters are not well understood. It is expected that through flexible process management, unknown conditions occur in the digester. They can endanger the undisturbed plant operation. It is therefor necessary to develop a strategy for innovative process monitoring and sample collection.

The aim of the investigtion is to evaluate and optimize the feeding management strategy in biogas plants. This strategy includes the combination of an innovative sensor in the liquid phase, model based monitoring and neural work as methodological approaches. This project is further divided into 3 different work packages:

- Package 1: Identification of crucial zones in the biogas digester
- Package 2: Installation and validation of the acoustic waveguide and near-infrared spectroscopy
- Package 3: Verification of developed models for a full scale biogas plant



Fluctuations in the dry matter content of grass silage measured over 6 months using the NIRS sensor

Funding:
Federal Ministry of Economic Affairs and Energy

Fachagentur nachwachsende Rohstoffe (FNR)

Partners:
Technical University - Berlin

SOTA Solutions (Berlin)

Project duration:
Aug. 2014 – March 2018

Optimization of the operation and design of biogas plants for needs-based, flexible and efficient biogas production taking into account process stability (OptiFlex)

Dr. Hans-Joachim Nägele

M. Sc. Philipp Kress

Dr. Andreas Lemmer

The expansion of the regeneratively operated electricity system requires optimized, flexible operation of existing and newly constructed biogas plants. However, the previously implemented solutions for flexible plant operation are too often characterized by the lack of cost-effectiveness.

As part of OptiFlex, an efficient system solution for stable plant operation is therefore being developed and demonstrated under practical conditions at the biogas plant of the University of Hohenheim. Already developed methods of model-based, flexible feeding and the hydrodynamic control concept will be merged and further developed. By comparing the practice installation with model predictions and laboratory investigations, the flexible operation mode can be further analyzed and optimized.

In addition to the equipment-technical adaptation, the project aims at the preparation of an instrumentation retrofitting of existing biogas plants. For this purpose, partners from research, plant construction and process automation work together on a comprehensive technical solution for optimized, flexible biogas plant operation.

Funding:
Federal Ministry of Food and Agriculture (BMEL)

Fachagentur nachwachsende Rohstoffe (FNR)

Partners:
Deutsches Biomasse-forschungszentrum (DBFZ)

Fraunhofer-Institut für Keramische Technologien und Systeme (IKTS)

Technische Universität Berlin (TU Berlin)

Maier Energie und Umwelt GmbH

Project duration:
Oct. 2017 – Sep. 2020

Research biogas plant on a practical scale at the Unterer Lindenhof with post digester (center, integrated gas storage) and two identical digesters (concrete roof with sampling ports)

Two-phase anaerobic digestion of sugar beet for biomethane production – Process optimization of preservation and conversion for the improvement of energy yield (ZRCH4)

The aim of this project is to offer the biogas plant operators an ecologically, energy-oriented and economically superior method. Our focus is to produce a high caloric biogas to be used as fuel or as SNG, which in turn provides an alternative to previous applications of electricity production.

To achieve this objective, we pursue a bilateral approach. We use the rarely-applied substrate sugar beet, which improves the ecology of the process and furthermore allows us to optimally use new process technology.

The first step is to develop a novel, optimal method to preserve the sugar beet. Accordingly, the results of storage tests and laboratory experiments are compared with those of conventional storage processes. As such, we are able to duly evaluate how preservation methods influence the energy yield.

The next step is to determine how suitable the ensiled sugar beets are for digestion within two-phase anaerobic digestion laboratory systems and to optimize crucial parameters. The new biological conversion processes are already able to fractionate the biogas during the production. This in turn significantly increases the methane content of the biogas. We are able to therefore reduce the cost of preparing biogas to a natural gas quality, and furthermore utilize the gas as a fuel. Producing biomethane could be an alternative for generating electricity using a CHP unit. The problem of using heat when converting biogas in a CHP unit is furthermore eliminated.

Although problematic in conventional biogas plants, sugar beet is an almost ideal substrate for the two-phase anaerobic digestion. With high sugar content and a low level of indigestible materials, such as lignin, sugar beet is very suitable for acidification.

M. Sc. Elzbieta Kumanowska

Armin Kinigadner

Dr. Simon Zielonka

Dr. Andreas Lemmer

Dr. Hans Oechsner

Vacuumed sugar beet silos shortly after filling

Funding:
Federal Ministry of Food and Agriculture (BMEL)

Fachagentur nachwachsende Rohstoffe (FNR)

Partner:
Novatech Corporation

Research Stations:
“Unterer Lindenhof“ and “Ihinger Hof”

Project duration:
Sept. 2014 – Feb. 2018

Optimized substrate management and how the composition of biogas digestate influences soil-nitrogen and soil-humus balance

B. Sc. Florian Siemeister

Dr. Hans Oechsner

The composition of the biogas digestate can very widely depending on the subsrate that is fed into the biogas plant. This can also mean that there is a variety of different fertilization effects by different biogas digestates. Whether there is an influence of pretreating the digestate before fertilizing has not yet been studied. As many plant operators lack storage capacity during the Winter months, a time when fertilizing the fields is prohibited, it has become common practise to fertilize in Autumn. As many plant operators lack storage capacity during the Winter months, a time when fertilizing the fields is prohibited, it has become common practise to fertilize in Autumn. This means, however, that digestate is lost during a season where the nitrogen demand of the soils is very low and should be available in Spring when nitrogen demand is high.

Established methods of fermentation residue treatment (dryers, vacuum evaporators) have been analyzed using a mass balance and checked for their efficiency. The aim is to develop an optimized process that allows nitrogen to be separated from the circuit and to provide a stockpile and storable fertilizer.

Over a measuring period of 3 weeks each, heat input and power consumption were measured for various vacuum evaporators and paddle dryers. Initial results of the vacuum evaporators show that the volume of fermentation residues could be reduced by 64 % through evaporation. For every kilowatt hour of heat used, 1.35 litres of distillate was produced. The current consumption during the measurement period was 17.1±2kW.

By providing a planning tool to optimize the estimation of the fertilizing effect of each fermentation residue by the plant operator, production recommendations can be provided for ecologically and economically sustainable biomass production systems.

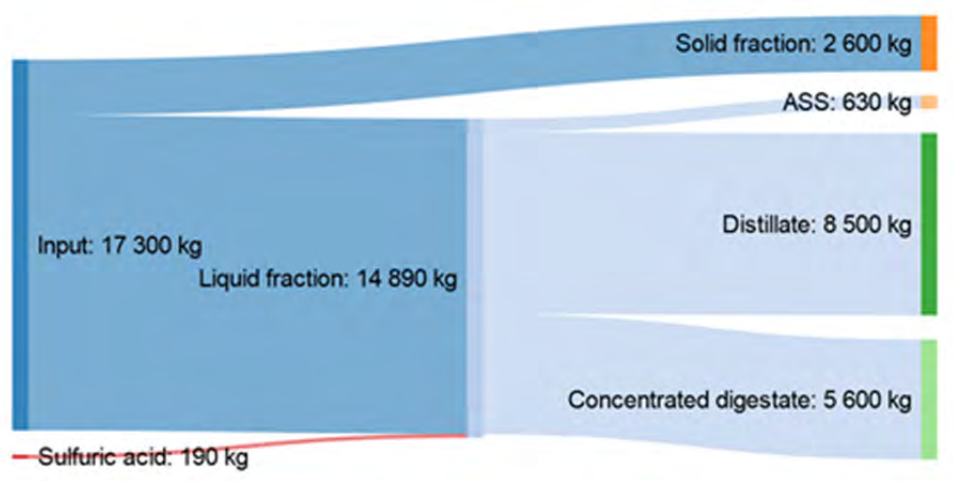
Funding:
Fachagentur für Nachwachsende Rohstoffe (FNR)

Partners:
University of Hohenheim
Fertilization and Soil Matter Dynamics (340i)
Institut of Crop Science

University of Hohenheim
Chair of Soil Science

Steinbeis Research Center

Project duration:
Nov. 2014 – April 2018



Daily mass balance in a vacuum evaporator system

Research into the use of N-rich and lignocellulosic biomass for biogas production: methane yield potentials, process stability and nutrient management

The first research objective is to investigate new prospective crops grown in Ukraine for biogas production. Plants, selected for methane yield potential analysis (HBT) are soybean, sorghum, sugar beet, maize, miscanthus, switchgrass and paulownia. In this study, different varieties, years of vegetation and harvesting dates of the selected plants are analyzed.

Within the second objective, different separation working modes for nutrient management in digestate will be investigated. This will allow the usage of digestate for fertilizing purposes in precision agricultural farming.

The third research objective is on the influence of nitrogen on biogas process stability: the study on microbial speed of adaption to changing and increasing N concentrations in the digester. During anaerobic digestion (AD) of N-rich feedstocks, ammonium nitrogen (NH_4-N) is produced. NH_4-N in the digester is represented as ammonium ions (NH_{4+}) and as a free ammonia (NH_3). With an increase in pH and temperature in the reactor, the percentage of NH_4-N present as free ammonia rises. Since NH_3 freely passes through the cell membranes of methanogenic germs, it causes a toxic effect to the bacterial activity and serious inhibition to the AD process. This inhibition can cause losses in methane production up to 30%.

The research on biogas process stability was carried out in the CSTR (continuous stirred-tank reactor) lab.-scale system. The ammonium increase in the reactors was achieved by increasing the N concentration in the feedstock. Inoculums with low and high N-contents together with different scenarios of N-increase during feeding were analyzed. Within the experimental period, the maximum N-concentrations in feeding of 10 and 12 g N / kg FM for inoculums with low and high N-contents respectfully, were reached.

M. Sc. Ievgeniia Morozova

M. Sc. Nadiia Nikulina

Dipl.-Ing. agr. Christoph Serve-Rieckmann

Dr. Andreas Lemmer

CSTR lab.-scale system used for the research on nitrogen

Funding:
German Academic Exchange Service (DAAD)

Partner:
Institute of Bioenergy Crops and Sugar Beet of the National Academy of Agrarian Sciences of Ukraine

Project duration:
Oct. 2016 – Nov. 2019

Bio-electrochemical production of high calorific biogas from waste materials (BioElektroGas)

M. Sc. Padma Priya Ravi

Armin Kinigadner

Dr. Andreas Lemmer

The aim of the research joint project is to convert biogenic waste to highly caloric biogas in compact and very efficient systems. The basis of the novel process is the combination of fermentative processes for the digestion of solid biomass with bioelectric systems for methane production, so-called microbial fuel cells. By means of this process combination, various substrates, such as market waste or feedstuffs, can be utilized flexibly. These organic residues are first fermentatively decomposed ("dark fermentation") at low pH values and converted into organic acids, which in turn are fed to the bioelectrochemical reactor.

The research group is to develop and test suitable anode and cathode materials for the microbial fuel cell. The electrode structure must also be adapted to the bio-chemical conversion processes. Further investigations are aimed at influencing the microorganisms at the electrodes. Finally, the overall fermentation-bioelectrochemical process has to be optimized at technical level in the laboratory scale at the state institute.

In the first test phase, hypermarket waste from “Bayha Gemüse”, Filderstadt, was used. This consisted of a mixture of carrots, carrot processing waste (puree), celery, cabbage and potatoes and thus showed typical components of hypermarket waste. The substrate mixture was fermented in a 2-stage system at various target pH values (5.5 and 6.0) in the acidification reactor. For both target pH values, the acid composition in the acidification reactor was examined. The quantities and compositions of gas produced were measured for the acidification stage and the subsequent methane reactor.

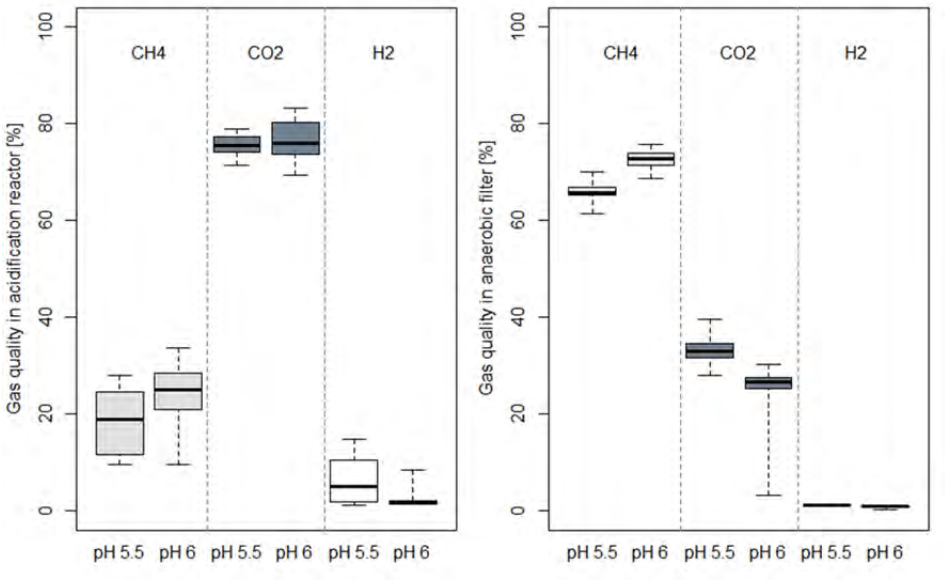
Funding:
Projektträger Karlsruhe – Baden Württemberg Programme

Partners:
Karlsruhe Institute of Technology (KIT)
Institute of Applied Biosciences (IAB)

University of Freiburg
Department of Microsystems Engineering (IMTEK)

University of Stuttgart
Institute for Sanitary Engineering, Water Quality and Solid Waste Management (ISWA)

Project duration:
Sep. 2015 – Aug. 2018



Effect of target pH-values in AR and AF on gas concentrations

Autogenerative Two-Phase High Pressure Fermentation (AG-HiPreFer)

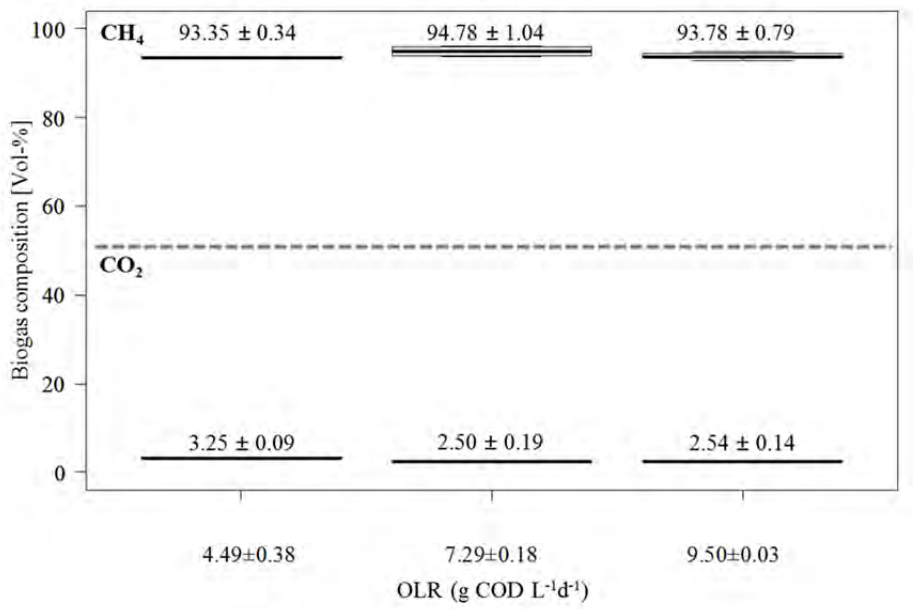
The aim of this project is to integrate biogas production, purification and pressure boosting within one process saving up to 30% of energy consumption for the gas conditioning by avoiding the compression.

Therefore a new, two-phase pressurized anaerobic digestion process, with autogenerative increase of the pressure in the digester up to 100 bar will be developed (AG-HiPreFer), producing biomethane of natural gas quality inside the methane reactor, which can then be fed directly into the grid. In contrast to the technologies commonly used, no additional chemicals or compression are needed. Moreover, this bio-physical process makes use of the fact that CO_2 is more soluble than methane, resulting in a higher CO_2 content in the liquid phase at increased pressures. Methane contents over 92% can be reached in the gas phase.

Additionally, studies to an anaerobic Microbial Fuel Cell (AMFC) integrated in the process will be done to increase the overall efficiency of the process.

In the project, appropriate measurement and control concepts for process monitoring at operating pressures up to 100 bar have to be established. A new membrane concept for separating acids formed during the fermentation process will be developed. Experiments on the solubility of gases in the methane reactor will be done as well as studies to clarify the influence of pressure on microbiological process in the methane reactor.

Moreover, basic research on the aMFC will be done, which uses the difference of the redox potential and hydrogen ions between the acidification reactor and the pressure methane reactor for a direct generation of electricity via carbon, stainless steel or iron cyanide electrodes. A system-analytical consideration and an economic evaluation of the process will round off the project.



Influence of different organic loading rates (OLR) at operation pressure 25 bar on gas quality in a continuous process

Dr. Wolfgang Merkle

Armin Kinigadner

Dr. Jonas Lindner

Dr. Simon Zielonka

Dr. Andreas Lemmer

Funding:
Federal Ministry of Education and Research (BMBF)

Partners:
DVGW-Research Centre at the Engler-Bunte-Institute of Karlsruhe Institute of Technology (KIT)

Johannes Gutenberg University Mainz, Institute of Microbiology and Wine Research (IMW)

Associated partner: Centre de Recherche Public Gabriel Lippmann, Département Environnement et Agro-biotechnologies (CRP), Luxemburg

Project duration:
July 2013 – May 2018

Development of efficient two-phase anaerobic digestion plants via coupled energetic and material utilization (Optigär)

M. Sc. Jörg Steinbrenner

Dr. Hans-Joachim Nägele

Dr. Hans Oechsner

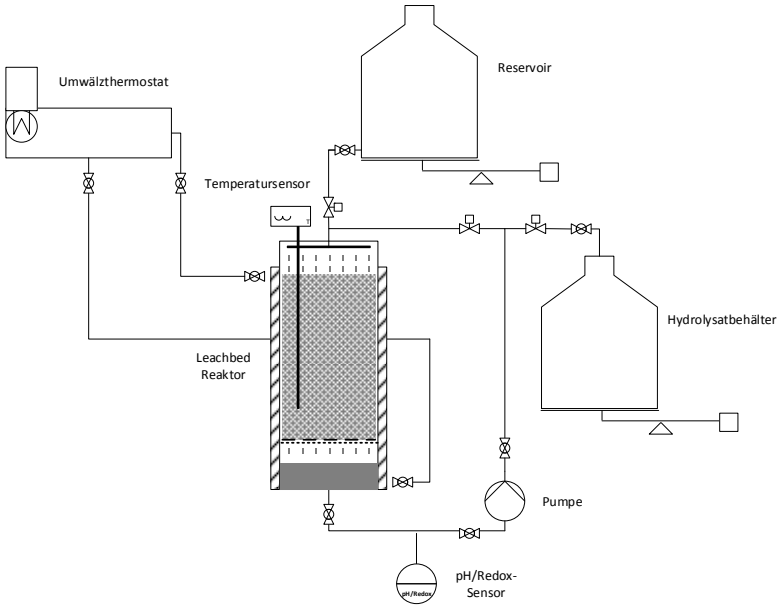
The overall objective of this project is the development of a procedure for a cascade use and thereby a sustainable and integral utilisation of agricultural raw materials. Here is the material use of coproducts as platform chemicals with potentially high prices in focus.

In this project, a new concept for integrated material use of two-phase biogas plants will be developed. With this approach, coupled material and energetic use of agricultural raw materials is to be enabled. To increase the concentration of usable platform chemicals in the hydrolysis process, variations of process parameters like temperature, organic loading rate, pH-value and buffering capacity and the addition of various additives (enzymes, microorganism cultures, buffer substances) and a specific feed material selection, will be tested to increase the concentration of usable platform chemicals. The produced hydrolysate will then be treated with selective membranes to separate valuable products. The residue of this process will be recycled in anaerobic digestion.

To optimize the yields of valuable substances, a screening of a variety of agri-cultural raw materials and of different reaction conditions to increase the yield of valuable products will be performed. The aim is to select suitable substrates and appropriate hydrolysis reaction conditions. For process control, the fermentation pro-ducts are regularly analysed by wet chemistry analysis.

The separation of the profitable acids via special membranes will be done by the Fraunhofer Institute for Chemical Technology (ICT).

In addition, the European Institute for Energy Research and the Lipp GmbH will perform profitability and life cycle assessments as well as develope a concept for industrial scale production.



Hydrolysis and acid formation in a leachbed reactor system

Funding:
Fachagentur Nachwachsende Rohstoffe (FNR)

Partners:
Frauenhofer Institute for Chemical Technology (ICT)

EiFER European Institute for Energy Research

Lipp GmbH

Project duration:
Sep. 2015 – Aug. 2018

Developing a procedure for the fermentative conversion of hydrogen by fluctuating sources of biomethane in biogas plants (H2-Transfer)

Biogas plants can metabolize H_2 and CO_2 to CH_4 by means of hydrogenotrophic methanogens present in the biocenosis. The direct entry and subsequent implementation of hydrogen in biogas plants is referred to as in-situ methanation and may be an important key position for existing biogas plants in a future post-EEG scenario. A conversion of the existing biogas plants into storage service providers would significantly increase the importance of biogas systems.

Methane production can be carried out both chemically-catalytically and biologically in biogas plants. For this purpose, the amount of carbon dioxide in the biogas is determined and four times the amount of hydrogen is added in the form of fine bubbles to achieve a complete methanation. As a result of CO_2 conversion, the proportion of methane in biogas increases. If necessary, this biogas can be raised to the methane concentration required for feeding into the natural gas network by means of a downstream fine cleaning. The system makes sense as a current transition system and allows the buffering of renewable surplus electricity in the natural gas grid. In addition, a temporal decoupling of power generation and consumption can be achieved.

Four identical 100 liter reactors are operated at a capacity of 2 kg oTS $(m^3\ d)^{-1}$. Gas quality and quantity, introduced amount of H_2, pH values, redox potential and fermenter temperature are recorded online. The percentage of hydrogen in the biogas is used to automatically adjust the amount of H_2 introduced. The resulting biogas is also partly recirculated. The conditions under which methane bacteria optimally convert the added hydrogen to methane are investigated.

Semi-stoichiometric hydrogen gasification was tested, resulting in a 36.6% increase in methane content and a 41.1% decrease in CO_2 content relative to the initial percent distribution. A hydrogen radical of 6.6% could also be measured. Room load variations and thermophilic temperatures will soon be tested.

M. Sc. Bernhard Lecker

Dipl.-Ing. agr. Christoph Serve-Rieckmann

B. Sc. Daniel Riehle

Dr. Hans Oechsner

Laboratory container for hydrogen injection experiments

Funding:
Ministry for Science Research and Art Baden-Württemberg „Bioökonomie-Projekte“

Partners:
DVGW Research Unit at Engler-Bunte-Institut (DVGW-EBI), KIT

Project duration:
June 2014 – Feb. 2018

Process development for the use of biological methanation in two-stage production of biogas; Subproject 1: Investigation of a fixed-bed fermenter and continuous stirred tank reactor (BioHydroMethan)

M. Sc. Lukas Illi

M. Sc. Bernhard Lecker

B. Sc. Daniel Riehle

Dr. Hans Oechsner

The planned expansion of renewable energies in Germany requires considerable storage capacity for electrical energy, which of this size, can only be provided by chemical energy carriers. The biological methanation of hydrogen in the biogas digester is a promising alternative to catalytic methanation.

Within this project, the two-stage digestion with a separate acidification stage and the targeted introduction of hydrogen into the methane reactor will be investigated. A particular advantage of this approach is that the produced carbon dioxide during the anaerobic digestion process can be used by hydrogenotrophic methane bacteria, which almost completely convert it to methane. Subsequently, the biogas can be injected into the natural gas grid as biomethane with, compared to conventional biogas, significantly lower treatment costs or can be used as fuel.

As part of this joint project, which consists of three sub-projects, technological tests with different reactor designs, such as anaerobic filters, continuous stirred tank reactors and membrane reactors are carried out on a laboratory scale. The development of a technique for fine bubble hydrogen injection, entering the digester liquid, will be a fundamental task in order to achieve an optimum supply for the archea. Additionally, the influence of bubble size, injection technique as well as the design of the bubble ascension on the transfer efficiency to the digester liquid and the methane bacteria will be examined. A special emphasis will be on the change in the biological community by adding hydrogen to the methane reactors. By measuring the composition and concentration of volatile fatty acids, the buffering capacity, the pH-value, the concentration of dissolved gases in the fermentor substrate and the quality of the resulting product gases, the reactor types will be evaluated, optimized and refined.

Funding:
Federal Ministry of Food and Agriculture

Fachagentur Nachwachsende Rohstoffe e.V. (FNR)

Partners:
DVGW Research Unit at Engler-Bunte-Institute (DVGW-EBI) – Water-chemistry and water-technology

Leibniz Institute for Agricultural Engineering Potsdam-Bornim (ATB)

Project duration:
May 2015 – May 2019

Fixed-bed reactors with feeding pump for biological methanation

Use of biological methanation for Power-to-Gas Concepts: Fermentative high-pressure methanation of hydrogen

The biological high-pressure methanation of carbon dioxide and hydrogen to methane is an interesting vector technology for the storage of surplus flow in natural gas networks. Carbon dioxide is converted microbiologically to methane in a pressure reactor by hydrogen produced by electrolysis from wind and solar energy. This "bio-natural gas" can be used as fuel in the area of mobility or fed into natural gas networks. The biological high-pressure methanation of hydrogen to methane is thus a solution approach for a sustainable energy supply in rural areas.

Within the scope of the project, a novel concept of multi-phase high-pressure trickle bed reactors is investigated for methanation, which can be connected downstream of a conventional biogas plant. Compared to alternative methods, this new approach has significant advantages. For example, the fixed bed allows intensive contact between microorganisms and gases and the increased reaction pressure of up to 10 bar improves the previously problematic gas solubility. As a result, high gas and methane yields are expected with this concept.

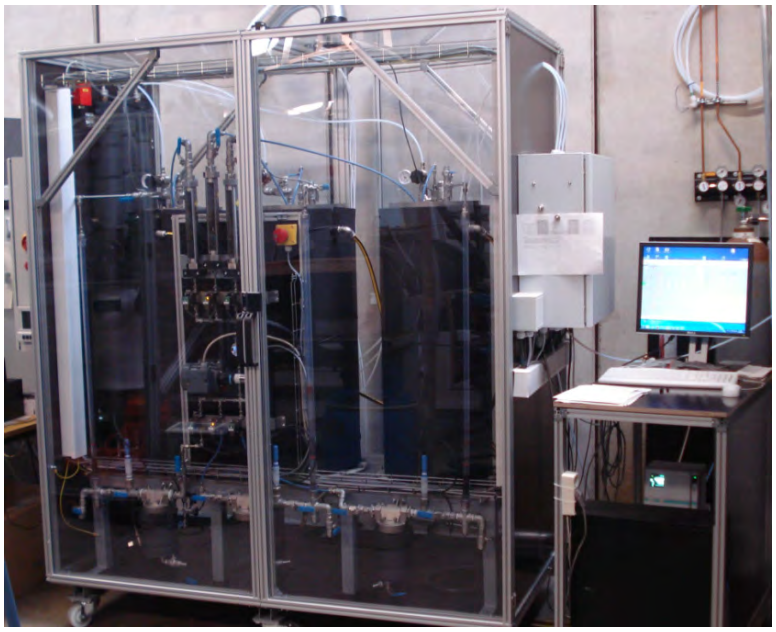
To this end, a laboratory system for the conversion of hydrogen and carbon dioxide into methane was initially planned and constructed, and equipped with measuring, control and regulation technology. Experimental series on the influence of the operating parameters, such as loading rates, residence time, pressure and temperature, are currently being carried out with regard to an increase in the gas and methane yields.

In initial preliminary tests, the functionality of the concept was successfully demonstrated. Thus, methane contents >97% and methane formation rates of 2.5 l (l d)$^{-1}$ were achieved in the three reactors realized.

M. Sc. Timo Ullrich

Armin Kinigadner

Dr. sc. agr. Andreas Lemmer



Facility at laboratory scale for fermentative high-pressure methanation of hydrogen and carbon-dioxide

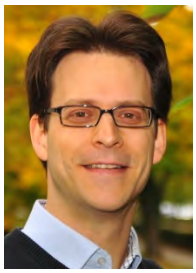
Funding:
Ministry of science, research and art Baden-Württemberg

Partners:
DVGW Research Unit at Engler-Bunte-Institute (DVGW-EBI)

Engler-Bunte-Institute of KIT (KIT-EBI)

Project duration:
June 2014 – Dec. 2017

Biogas plants after the EEG phase - Business models of an energy self-supply of agricultural holdings by means of their biogas plants - Evaluation of practice plants (Biogas_autark)



Dr. Simon Zielonka

For many farms biogas plants have become a fixed part of the business. Due to the new regulations in the EEG, the continued existence of these facilities is seriously endangered. The overriding goal for biogas production was and still is - in the context of current sustainability criteria - to be economically viable without government subsidies. In this sense, the biogas industry is currently too dependent on the EEG.

The aim is to find ways to produce biogas without government subsidies. To this end, increased or complete own use of the energy produced by the biogas plant on the farm would be a possible future prospect. The focus is on farms that, due to their energy needs, have the opportunity to use the produced electricity and heat themselves. In addition, the field of fuel production and use is checked.

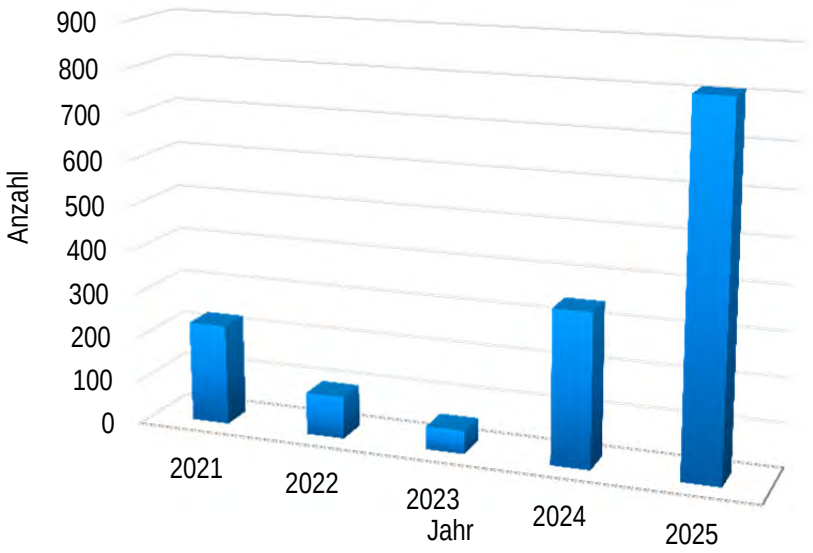
In the process, economic perspectives for individual agricultural biogas plants are to be worked out and recommendations for action developed on the basis of these results. Only agricultural biogas plants are explicitly considered in order to determine an optimized energy use of the biogas plant in concrete agricultural operations in relation to the various production processes. On the one hand, the findings will be worked out as a bottom-up analysis for farms with biogas plants. On the other hand, a cluster analysis draws conclusions about the nationwide effects and potentials for the existing plant park.

Funding:
Federal Ministry of Food and Agriculture

Fachagentur für Nachwachsende Rohstoffe e.V.

Partner:
Institut für ZukunftsEnergie- und Stoffstromsysteme gGmbH (IZES)

Project duration:
Oct. 2017 – Sep. 2019



Number of closures of biogas plants by 2025, assuming a term of 20 years (IZES gGmbH)

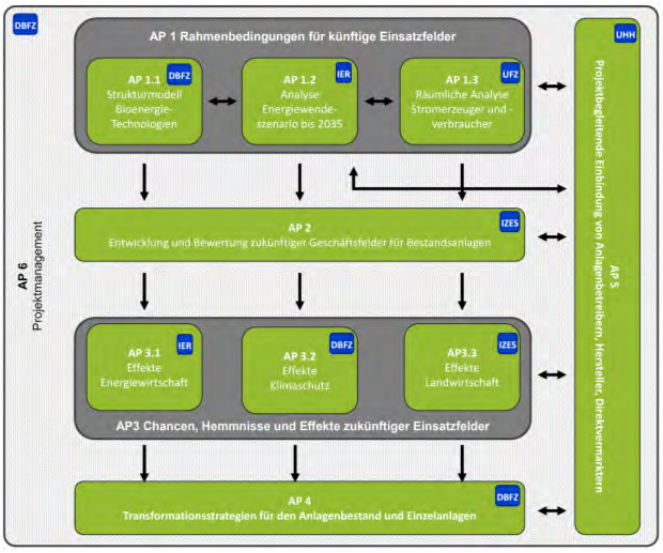
Bioenergy - Potentials, long-term perspectives and strategies for electricity generation plants after 2020 - Stakeholder involvement (BE20Plus)

Dr. Simon Zielonka

Bioenergy contributes significantly to renewable electricity and heat production within the German energy transition. In 2015, about 27% of renewable electricity and 88% of renewable heat came from bioenergy plants. The expansion and operation of bioenergy plants for the generation of electricity has been promoted in recent years primarily by the EEG, under which the facilities were previously set for a period of 20 years fixed rates. Since most of the bioenergy plants for electricity production were built in the years between 2004 and 2014, the EEG support will expire for this part of the plant portfolio in the years 2025 to 2035.

The aim of the research project is to evaluate which business models are suitable for existing plants in order to ensure continued operation beyond the previous compensation period, possibly also with a changed operational focus.

In addition to an evaluation of data inventories of existing plants, calculations are also to be made on the basis of selected individual plants, which will investigate the potential for increasing revenues and reducing costs. In addition to the option of transferring existing systems into the tender design created with the 2017 EEG amendment, further business models and operating strategies will be examined by way of example. Beyond the consideration of the individual plants, it should also be assessed comprehensively how and to what extent bioenergy plants can contribute in the future to a sustainable, economical and secure energy supply. For this purpose, statements on the medium-term development of the asset portfolio are to be derived on the basis of modeling approaches. Furthermore, regional effects on the electricity and heat supply, the changing contributions of bioenergy to the reduction of greenhouse gas emissions as well as the resulting effects on agriculture and forestry will be presented.



Work packages and workflow in project BE20Plus (Dotzauer 2017)

Funding:
Federal Ministry of Food and Agriculture

Fachagentur für Nachwachsende Rohstoffe e.V.

Partners:
Deutsches Biomasse Forschungszentrum gGmbH (DBFZ)

Institut für ZukunftsEnergie- und Stoffstromsysteme gGmbH (IZES)

Helmholtz Centre for Environmental Research (UFZ)

University of Stuttgart Institute of Energy Economics and Rational Energy Use (IER)

Next Kraftwerke GmbH

Project duration:
Nov. 2017 – Oct. 2019

BIOGAS PROGRESSIV – forward-looking strategies for agricultural biogas plants (ProBiogas)

Dr. Wolfgang Merkle

Dr. Hans Oechsner

A variety of approaches for optimizing biogas production have already been developed and determined in research projects from universities, agricultural research institutes and industry. However, a systematic evaluation of these approaches with regard to their usability in practicable business models and a range of information on this optimization geared to the operators of biogas plants and biogas consulting is still missing.

The aim of the project "BIOGAS PROGRESSIVE" is to provide a comprehensive range of information with the help of which plant operators and consultants are able to identify and develop suitable concepts for biogas plants.

In order to achieve this goal, a comprehensive data collection will be carried out at research facilities, manufacturers of plant components and biogas plants that have already implemented innovative concepts. These data, together with the information already available to the project partners, are the basis for the development and evaluation of optimization measures. These measures are combined into process models that represent viable business models for the operation of biogas plants. All measures and models are evaluated technically, economically and ecologically with the help of practical feasibility studies.

The result is a comprehensive and professionally secured information service for plant operators, agricultural consultants specializing in biogas, planning offices, municipalities, licensing authorities, banks and investors. Decision makers from politics and administration are also addressed. The know-how transfer takes place with the help of free online applications, target-group-specific specialist events, a specialist portal on the KTBL homepage and publications in various formats.

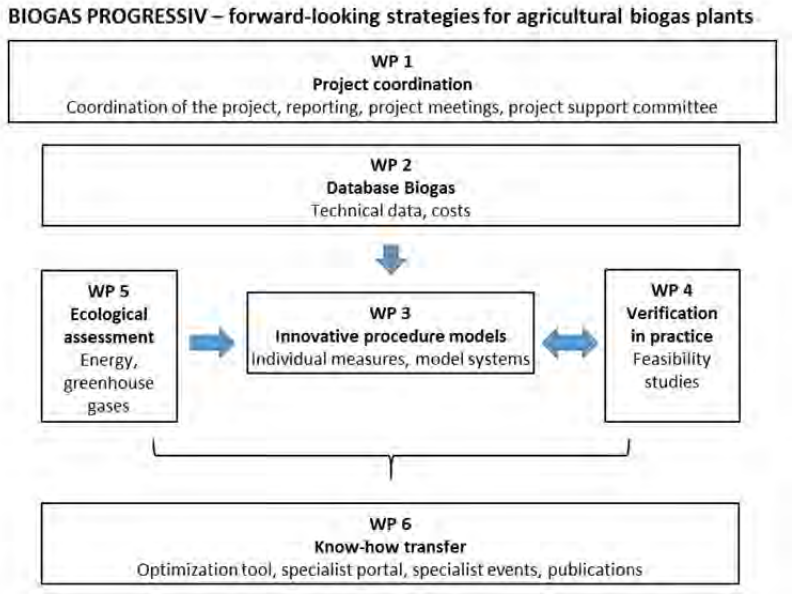
Funding:
Federal Ministry of Food and Agriculture

Fachagentur für Nachwachsende Rohstoffe e.V.

Partners:
Association for Technology and Structures in Agriculture (KTBL), Darmstadt

Landwirtschaftskammer Niedersachsen, Fachbereich Energie, Bauen, Technik, Oldenburg

Project duration:
Dec. 2017 – Nov. 2020



Working packages in the project "BIOGAS PROGRESSIV – forward-looking strategies for agricultural biogas plants"

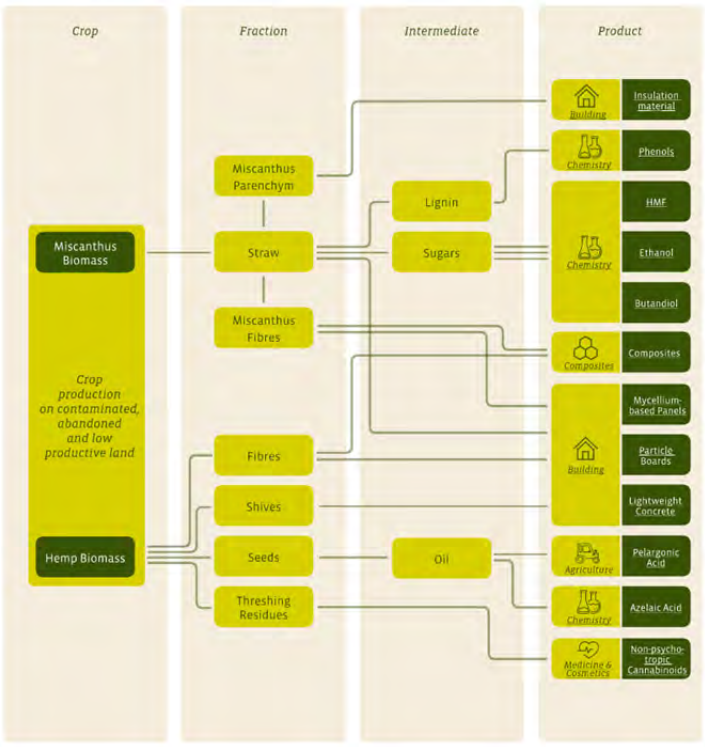
GRowing Advanced industrial Crops on marginal lands for biorEfineries (GRACE)

The BBI demonstration project “GRowing Advanced industrial Crops on marginal lands for biorEfineries” (GRACE) is a € 15 million project, which aims at optimizing different value chains for miscanthus and hemp.

The consortium consists of 22 partners from universities, agricultural companies and industry. The project is coordinated by the University of Hohenheim in Stuttgart (Germany).

The goal of the project is to produce sustainable products with a strong market potential, to guarantee a reliable and affordable supply of sustainably produced biomass, and to better link biomass producers with the processing industry. In order to avoid competition with the cultivation of food or feed crops, miscanthus and hemp are grown on areas that have been polluted by heavy metals, for example, or are unattractive for food production due to lower yields.

The work of the State Institute for Agricultural Engineering and Bioenergy is nested into the development and optimization of Hydroxy-Methyl-Furfural (HMF) production from miscanthus. HMF is a base chemical that can be used to produce plastic bottles for example. To close the loop, the byproducts from the HMF production can be used to produce biogas. The fermentation residues can then go back to the field as fertilizer.



Overview of the recycling paths in the GRACE project

Dr. Johannes Krümpel

Dr. Andreas Lemmer

Funding:
Bio-based Industries Joint Undertaking (BBI JU)

Partners:
Wageningen University
INRA
Aberythwyth University
Università Cattolica del Sacro Cuore
University of Zagreb
Novamont S.p.A.
Mogu Srl
AVA Biochem BSL AG
Addiplast SA
INA d.d.
Indena SpA
C.M.F. GREENTECH S.R.L.
Consorzio di Bonifica di Piacenza
Gießereitechnik Kuehn
Ecohemp S.r.l.
Miscanthusgroep
Terravesta
Vandinter-Semo
NovaBiom
Johannes Furtlehner
Cluster SPRING

Project duration:
June 2017 – May 2022

Demonstration of dry fermentation and optimization of biogas technology for rural communities in the MENA region (BIOGASMENA)

B. Sc. Nadiia Nikulina

Dr. Hans Oechsner

Funding:
ERANETMED

German Aerospace Center (DLR)

Partners:
State Institute of Agricultural Engineering and Bioenergy - University of Hohenheim (Coordination)

FnBB e.V.

Institut Nationa de la Recherche Agronomique (INRA)

Nenufar SAS

ERM Energies

University of Verona

Fundación IMDEA Energy

Agricultural University of Athens

University of Cyprus Nireas-IWRC

RTD TALOS Limited

S.K. Euromarket LTD

Centre de Biotechnologie de Sfax

EGE University

Universite Sciences et Technologie d'Oran (USTO)

Cairo University

Project duration:
Sep. 2017 – Aug. 2020

In rural areas of the MENA region, communities face multiple challenges: insufficient infrastructure for waste treatment, limited access to cheap energy, particularly electricity, poor soil fertility and water retention capacity.

The BIOGASMENA project is aimed at solving these issues, faced by agrarian communities, by means of treatment and stabilization of organic waste into high-quality, pathogen-free compost and use of biogas in raw form as low-cost fuel for domestic needs or through conversion into electricity in a generator. The project has the following objectives:

- bench-scale dry fermentation trials for process optimization;
- methane potential assays and characterization of digestate
- investigation of the combination of microalgae cultivation with biogas technology;
- planning, installation, and monitoring of a small-scale pilot plant of 5m^3, with a planned electrical power of 500W in Tunisia;
- performance of LCA and techno-economic analyses of designs;
- training and mobility of young researchers from the ERA and MENA region to EU;

Informing the research community, farmers in the MENA region and the public about biogas technology by means of a project website, workshops and project conferences.

The project is intended to develop biogas technologies, environmental-friendly microalgae cultivation, to improve decentralized waste treatment and energy supply as well as fertility in rural communities of the MENA region. The project will also have an impact on environmental and socio-economic levels, for instance, increasing in career opportunities for young researchers and development of local expertise and management of renewable energy projects.

Members of the research network BiogasMena at the kick-off meeting in December 2017

Detecting the methane emission potential of exemplary waste fermentation plants

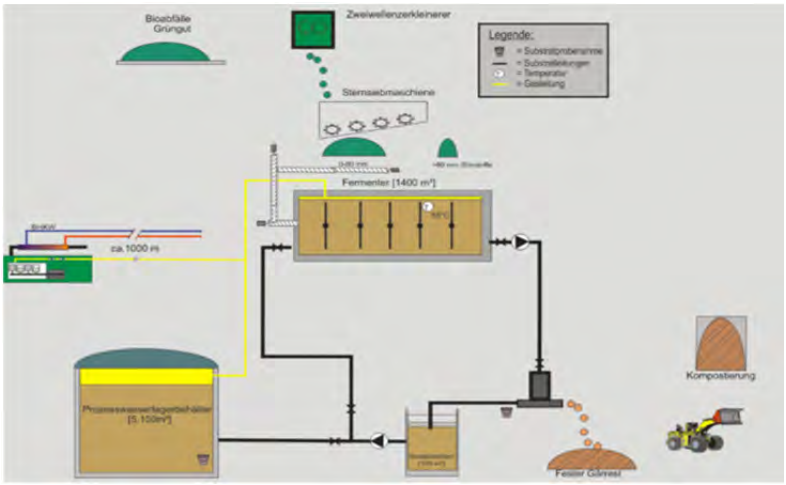
B. Sc. Tobias Bauer

Dr. Hans Oechsner

In the municipal area, due to preference of composting, only a few fermentation plants can be found. This means that value creation options (biogas and energy production) are lost. The expansion of biowaste digestion should therefore be promoted. Since biowaste costs nothing, the operators of the plants often lack the incentive to generate as much methane from the organic raw material as possible. Therefore, the hydraulic retention times of existing plants are often very short compared to agricultural biogas plants. This sometimes leads to low efficiency of these plants and the risk of uncontrolled methane emissions from non-gastight covered digestion residue storages.

On behalf of the LUBW, data was collected on five waste biogas plants in Baden-Württemberg in order to be able to carry out an ecological classification of these plants. In close cooperation with the operators of these anaerobic digestion plants, the input and output flows were recorded and substrate samples were analyzed for the methane yield and emission potential. The data collection showed that the plants often have only a hydraulic residence time in the range of <20 days. Most of the digestion residue is separated directly after the digester and the solids are fed to a composting stage (recycling). The separated, still warm liquid is usually stored in non-gastight covered tanks, sometimes even open. This causes high emission risks.

The investigations showed clear differences between the different plants. When considering the liquid phase only, a residual methane potential (37°C digestion temperature) up to 9% was measured. A better example is with a gas-tight effluent storage tank, where an emission potential (20°C) below 1% was determined. As it is hoped that more organic waste digestion plants will be built in the municipal area in the near future, it is recommended during the planning phase to ensure an optimal digestion technique with a sufficiently long hydraulic retention time and to ensure that the fermentation residue storage is as gas-tight as possible. This pays off both through higher utilization of biogas and through the protection of the environment.



Scheme of one of the plants investigated in the project

Funding:
LUBW Baden-Württemberg

Ministerium für Umwelt, Klima und Energiewirtschaft Baden-Württemberg

Project duration:
June 2016 – March 2017

The chemical laboratory of the State Institute of Agricultural Engineering and Bioenergy

Dipl.-Biol. Annette Buschmann

Jacqueline Kindermann

In the chemical laboratory of the State Institute of Agricultural Engineering and Bioenergy, comprehensive chemical analyzes were carried out in 2017 for the process biological assessment of fermentation processes for ensiling, biogas production or biological production of platform chemicals in a wide variety of projects.

For this purpose, the already proven, modern laboratory equipment was used such. a gas chromatograph (GC), a high pressure liquid chromatograph (HPLC), a powerful analyzer for simultaneous analysis of total carbon (TC), inorganic carbon (TIC) and total nitrogen (TN) from aqueous samples, and the TC content of solid samples, a digestion and distillation system for determination of total and ammonium nitrogen by Kjeldahl method from both aqueous and solid samples.

In addition to the already existing analyzers, the acquisition of a mass spectrometer with inductively coupled plasma (ICP-MS = inductively coupled plasma mass spectrometry) was also realized in 2017. Currently, the conversion work for the installation of the ICP-MS is taking place.

With the ICP-MS, trace element analyzes can be performed in the parts per trillion (ppt) range. The detection limits are generally below 100 ppt. The analyzes make a significant contribution to understanding and assessing the nutrient and trace element supply of various fermentation processes. So far, trace element analyzes of selected samples have been carried out in external laboratories. The expansion of the laboratory equipment pool by the ICP-MS enables a much faster and more cost-effective analysis of process-relevant ingredients. Above all, the concentrations of the following elements are interesting: phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), sodium (Na), iron (Fe), nickel (Ni), Cobalt (Co), manganese (Mn), copper (Cu) and zinc (Zn). Both liquid and solid samples can be tested. The sample preparation for the analysis of trace elements in ICP-MS is carried out by microwave digestion with aqua regia. An appropriate digestion device has also been purchased (CEM Microwave Laboratory System Discover / Explorer SP D / SP). The remodeling work in the laboratory to install this device is complete. The device has been installed and is ready for use.

The new device for microwave digestion of samples for determination in ICP-MS

Research biogas plant "Unterer Lindenhof"

On behalf of the Rectorate, the State Institute of Agricultural Engineering and Bioenergy takes over the operational management and the coordination of research projects at the biogas plant "Unterer Lindenhof". In addition to the general tasks of the operational management, in 2017, the support of the new building of the effluent storage tank was the focus of the State Institutes tasks.

So far, the liquid effluent at the research biogas plant has been stored after separation from the post digester in six open tanks of 500 m³ each. In 2017, four of the existing tanks were demolished and replaced by a new gastight sealed effluent storage with a volume of 4,800 m³. Intensive monitoring of the project in the planning and implementation phase by the State Institute should ensure that the scientific and technical requirements for the expansion of the large-scale research facility "biogas plant" are implemented in the best possible way. At the same time, despite the construction phase, a largely trouble-free research operation had to be ensured.

From an ecological point of view, the methane, ammonia and odor emissions as a result of the fermentation product storage are considerably reduced by the new, gas-tight covered fermentation product storage. The extended storage possibility of the fermentation products of up to 270 days leads to the fact that these are applied in the future only in the main vegetation time. The gas storage facility, which is enlarged to over 1,800 m³, makes it possible to carry out investigations on demand-oriented biogas production. In combination with the new CHP with an electrical output of 355 kW, future topics such as load-dependent, decentralized power and heat production can be processed to stabilize the grids.

With the construction of the effuent storage tank, the over 45-year-old manure technology of the research station "Lindenhöfe" was redesigned with the corresponding control and a new test stand for separators was integrated into the slurry system. With the completion of the construction project in spring, the future viability of the research instrument "Biogas plant Unterer Lindenhof" will be significantly improved.

Das neue Gärrestlager während der Bauphase

Dr. Andreas Lemmer

Dr. Hans-Joachim Nägele

Funding:
University of Hohenheim

University Building Department of Stuttgart and Hohenheim

Duration:
2017 - 2018

Progress in Biogas IV - international conference (PIB IV)

Dr. Hans Oechsner

All employees of the state institute

The international, scientific conference "Progress in Biogas" took place for the fourth time in Stuttgart from 08 to 11.03.2017. The two-day symposium with three parallel sessions is organized in cooperation with the IBBK and offers high-quality, international scientific lectures, a poster exhibition, an evening event, excursions and a company fair. On the third day, 4 practical workshops on hygiene, nitrogen-rich substrates, measurement technology, process stability and mechanical processing technology were offered. For the second time, a special issue of the scientific peer reviewed journal Bioresource Technology was developed for the conference. There were 73 lectures and 17 short lectures on the following thematic blocks and about 60 posters were presented:

- Low-tech biogas plants
- Biogas generation from biowaste and wastewater treatment plants
- Digestate application and management
- Process control, modeling of the biogas process
- Process inhibition (N-rich substrates)
- Innovative digestion technologies
- Pretreatment technologies
- Self-sufficiency and safety of energy supply
- Gas cleaning - gas processing
- Optimal integration of biogas in the energy system

Impressions of the conference Progress in Biogas IV in Hohenheim

Partner:
IBBK

Date:
08.03.-10.03.2017

Co-organized Conferences

Biogas Info Tage
18.-19.01.2017, Ulm Fairs, Ulm, organised together with renergie Allgäu e.V.

Biogastag Baden Württemberg
16.02.2017, Universität Hohenheim, Stuttgart, organised together with the Baden-Württemberg regional groups of the Fachverband Biogas

Progress in Biogas IV
08.–10.03.2017, Universität Hohenheim, Stuttgart, organised together with IBBK

International Biogas & AD Training Course
24.-28.04.2017, Stuttgart, ZIMT, organised together with IBBK

ALB Fachtagung - „Schweinehaltung“
16. März 2017, Universität Hohenheim, Stuttgart, organised together with ALB Baden-Württemberg

ALB Fachveranstaltung - „Energieeffizienz in der Landwirtschaft – Schwerpunkt Tierhaltung“
27. April 2017, organised together with ALB Baden-Württemberg

ALB Fachgespräch - „Perspektiven der Milchviehhaltung in kleinen Betrieben“
23. November 2017, St. Märgen, organised together with ALB Baden-Württemberg

International Guest Scientists to the State Institute

Edmond Demollari
"Evaluation and optimization of indicator parameters of biogas production from agricultural waste"
Agricultural University of Tirana, Albania

Adam Kwiatecki
"Methane yield determinations and investigations on nitrogen-rich substrates"
Poznań University of Life Sciences - Institute of Biosystems Engineering, Poland

Joanna Chwarscianek
„Investigation of methane yield potentials“
Poznań University of Life Sciences - Institute of Biosystems Engineering, Poland

Huicai Cheng
„Investigation of methane yield potentials“
Biological Research Institute, Hebei Provincial Academy of Science, China

Carlos M. Martinez Hernández
„Comparing Biogas Science: Cuba - Germany“
Universidad Central "Marta Abreu" de las Villas, Santa Clara, Villa Clara, Kuba

Alberto Miranda
“Planning a Biogas Laboratory for Costa Rica”
Universidad de Costa Rica, San Jose, Costa Rica

Graduate Theses 2017

Doctoral Theses

Johannes Krümpel
Demand-driven biogas production in anaerobic filters. Dissertation, University of Hohenheim.
http://opus.uni-hohenheim.de/volltexte/2017/1357/pdf/Diss_Johannes_KruempelOV.pdf

Wolfgang Merkle
Two-stage high pressure anaerobic digestion for biomethane production. Dissertation, University of Hohenheim.
http://opus.uni-hohenheim.de/volltexte/2017/1403/pdf/20170908_Dissertation_Merkle_Endversion_VDI_MLG.pdf

Staff of the State Institute who partake in a doctorate within the faculty of agricultural sciences are scientifically supervised by the Senior Head of the State Institute, Prof. Dr. Thomas Jungbluth.

Master Theses

Garzón Horta, E. A.
The influence of trace elements in biogas production determined by Hohenheim Biogas Yield Test (HBT) with different combination of inoculums and substrates

Jeen J.
Anaerobic digestion of Jatropha Seed Oil Extraction Residue: Process stability, Specific Methane Yield and Phorbol Ester Degradation

Haag, B.
Comparison of the biogas markets France and Germany with regard to legal framework and plant engineering

Urunuela-Saldana, M.
Mass balance of a two-stage anaerobic digestion process for hydrogen and methane production from sugar beet silage. In cooperation with the Institute for Sanitary Engineering, Water Quality and Solid Waste Management (ISWA) of the University of Stuttgart

Bachelor Theses

Bauer, T.
Recording the methane emission potential of biowaste fermentation plants by determining the residual methane potential

Kinigadner, A.
Planning, construction and test operation of a fixed bed reactor plant for biological high-pressure methanation on a laboratory scale

Grüner, J.
Comparison of the stirring quality of a bionic agitator to standard agitators in the practical biogas fermenter

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Bierer, B.; Nägele, H.-J.; Perez, A.O.; Wöllenstein, J.; Kress, P.; Lemmer, A.; Palzer, S.:
Real-Time Gas Quality Data for On-Demand Production of Biogas. 2018, Chemical Engineering and Technology, doi.org/10.1002/ceat.201700394, In print

Krümpel, J.H.; Illi, L.; Lemmer, A.:
Intrinsic gas production kinetics of selected intermediates in anaerobic filters for demand-orientated energy supply. 2018, Environmental Technology (United Kingdom), pp. 1-8. doi.org/10.1080/09593330.2017.1308439, In print

Lemmer, A.; Krümpel, J.:
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Demand-driven biogas production by flexible feeding in full-scale – Process stability and flexibility potentials, 2017, Anaerobe, Volume 46, pp. 86-95

Merkle, W.; Baer, K.; Lindner, J.; Zielonka, S.; Ortloff, F.; Graf, F.; Kolb, T.; Jungbluth, T.; Lemmer, A.:
Influence of pressures up to 50 bar on two-stage anaerobic digestion. 2017, Bioresource Technology, Volume 232, Pages 72-78, doi.org/10.1016/j.biortech.2017.02.013,

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Innovative additives for chemical desulphurisation in biogas processes: A comparative study on iron compound products. 2017, Biochemical Engineering Journal, Volume 121, Pages 181-187. doi.org/10.1016/j.bej.2017.01.006

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Putting the discussion on biogas on an objective footing is absolutely essential. 2017, Landtechnik, 72(5), pp. 263-264, doi.org/10.15150/lt.2017.3172

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Effect of agitation time on nutrient distribution in full-scale CSTR biogas digesters. 2018, Bioresource Technology, 247, pp. 1-6, doi.org/10.1016/j.biortech.2017.09.054

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Influence of operating pressure on the biological hydrogen methanation in trickle-bed reactors, 2018, Bioresource Technology, Volume 247, pp. 7-13, doi.org/10.1016/j.biortech.2017.09.069.

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Effect of trace element supplement on bio-methane performance of coffee husk and pulp. International conference “Progress in Biogas IV” 8.-11.03.2017, University of Hohenheim, Stuttgart, pp. 45

Grohmann, A.; Fehrmann, S.; Haag, N.L.; Stevens, P.; Vainshtein, Y.; Nägele, H.-J.; Wiese, F.; Bryniok, D.; Kempter-Regel, B.; Oechsner, H.; Hartsch, T.; Sohn, K.; Grumaz, C.:
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Haag, N.L.; Luff, K.; Oechsner, H.:
Competitive analysis of specific methane yields from continuous and batch processes for anaerobic digestion of bio-based products. International conference “Progress in Biogas IV” 8.-11.03.2017, University of Hohenheim, Stuttgart, pp. 142 – 143

Illi, L.; Lecker, B.; Oechsner, H.:
Wasserstoffmethanisierung bei zweiphasiger Prozessführung. 5. FNR/KTBL-Congress „Biogas in der Landwirtschaft – Stand und Perspektiven“, FNR/KTBL., 26.-27.10.16, Bayreuth, KTBL-Schrift 512, p. 410

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Flow velocity in CSTR biogas digesters: a full-scale study. International conference “Progress in Biogas IV” 8.-11.03.2017, University of Hohenheim, Stuttgart, p. 111

Krümpel, J.; Lemmer, A.:
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Kumanowska, E.; Zielonka, S.; Oechsner, H.:
Zweiphasige Vergärung von Zuckerrüben zur Biomethanerzeugung. 5. FNR/KTBL-Congress „Biogas in der Landwirtschaft – Stand und Perspektiven“, FNR/KTBL., 26.-27.10.16, Bayreuth, KTBL-Schrift 512, p. 369

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Biological hydrogen methanation - a review. International conference “Progress in Biogas IV” 8.-11.03.2017, University of Hohenheim, Stuttgart, p. 83

Lemmer, A.; Merkle, W.:
Effects of high pressure anaerobic digestion up to 30 bar on pH-value, solubility of CO_2 and specific methane yield. International conference “Progress in Biogas IV” 8.-11.03.2017, University of Hohenheim, Stuttgart, p. 87

Lindner, J.; Miroshnichenko, I.:
Biogas potential of livestock farming residuesin the Belgorod region in Russia. International conference “Progress in Biogas IV”, 8.-11.03.2017, Stuttgart-Hohenheim, p. 54

Meissner, K.; Awiszus, S.; Reyer, S.; Grumaz, C.; Bach, M.; Cossel, M.; Steinbrenner, J.; Müller, T.; Oechsner, H.; Lewandowski, I.; Sohn, K.; Müller, J.:
Gobi - General optimization of biogas processes. International conference “Progress in Biogas IV” 8.-11.03.2017, University of Hohenheim, Stuttgart, pp. 137 - 139

Nägele, H.-J.; Kress, P.; Oechsner, H.:
Optimierung des Rühraufwandes bei Biogasanlagen zur Einsparung des Energieverbrauches. 5. FNR/KTBL-Congress „Biogas in der Landwirtschaft – Stand und Perspektiven“, FNR/KTBL., 26.-27.10.16, Bayreuth, KTBL-Schrift 512, p. 296

Nägele, H.-J.; Steinbrenner, J.; Hermanns, G.; Holstein, V.; Haag, N.L.; Oechsner, H.:
Innovative additives for chemical desulphurisation in biogas processes: A comparative study on iron compound products. International conference “Progress in Biogas IV” 8.-11.03.2017, University of Hohenheim, Stuttgart, p. 72

Oechsner, H.:
Process control and troubleshooting. In: Influencing factors in the biogas process – Workshop Khon Kaen, Thailand, 25. Juli 2017

Oechsner, H.:
Biogas generation with fibrous substrates - a study with horse manure. In: 7th International Conference on Fermentation Technology, 25th to 28th July 2017, Khon Kaen, Thailand, pp. 28-29

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Valorisation of organic platform chemicals in the biogas process chain. International conference “Progress in Biogas IV” 8.-11.03.2017, University of Hohenheim, Stuttgart, pp. 79 – 80

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Fermentative Conversion of Vegetable Waste in Two-Stage Biogas Systems. International conference “Progress in Biogas IV” 8.-11.03.2017, University of Hohenheim, Stuttgart, p. 107

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Surendra, K.C.; Ogoshim R.; Reinhardt-Hanisch, A.; Oechsner, H. Hashimoto, A.G.; Khanal, S.K.:
High yield tropical energy crops for bioenergy production: effect of plant components, harvest years, and locations on biomass composition and subsequent biogas production. International conference “Progress in Biogas IV” 8.-11.03.2017, University of Hohenheim, Stuttgart, p. 24

Ullrich, T.; Lemmer, A.:
Use of biological methanation of PtG-Concepts: Fermentative high-pressure methanation of hydrogen. International conference “Progress in Biogas IV” 8.-11.03.2017, University of Hohenheim, Stuttgart, p. 86

Presentations

Chala, B.; Latif, S.; Oechsner, H.; Müller, J.:
Effect of trace element supplement on bio-methane performance of coffee husk and pulp. International conference “Progress in Biogas IV” 8.-11.03.2017, University of Hohenheim, Stuttgart

Grohmann, A.; Fehrmann, S.; Haag, N.L.; Stevens, P.; Vainshtein, Y.; Nägele, H.-J.; Wiese, F.; Bryniok, D.; Kempter-Regel, B.; Oechsner, H.; Hartsch, T.; Sohn, K.; Grumaz, C.:
Unravelling of microbial dark matter dynamics related to ensilage and reactor performance in the biogas process chain. International conference “Progress in Biogas IV” 8.-11.03.2017, University of Hohenheim, Stuttgart

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Strömungsverhalten von Gärsubstraten in Abhängigkeit der Rührwerkstechnik & Einfluss einer flexiblen Fütterung auf Gasproduktion und Gasqualität. 7. Triesdorfer Biogastag, 16.01.2017, Triesdorf

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Bedingungen zur Inaktivierung von Unkrautsamen im Biogasprozess. Biogas-Infotage 2017, renergie Allgäu e.V., 18.-19.01.2017, Ulm

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