UNIVERSITY OF HOHENHEIM

Annual Report 2019

State Institute of Agricultural Engineering and Bioenergy

LANDESANSTALT für Agrartechnik & Bioenergie

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

The State Institute of Agricultural Engineering & Bioenergy

The State Institute of Agricultural Engineering and Bioenergy is a special department of the University of Hohenheim and aims to fulfill the following statutory tasks:

- Practical research
- Specialized consultation for agriculture in Baden-Württemberg
- Technical consultation for commercial and industrial enterprises
- Providing advanced education for future teachers and consultants in the field of agricultural administration, particularly regarding state of the art technology and new research

For many years, the State Institute has dedicated itself to specialized topics such as biogas production and questions concerning the bioeconomy, but the scope of its focus has expanded in recent years to encompass teaching at the university level as well. Through the habilitation of Dr. Andreas Lemmer and his appointment as an adjunct professor, several teaching tasks can now be fulfilled directly and others are provided by the new head of the State Institute, Prof. Joachim Müller. The topic of biogas has became an integral part of the NAWARO and agricultural science study programs. Students approach their bachelor's and master's thesises through the framework of research projects and gain valuable hands-on experience as research assistants for the State Institute. Doctorate students employed by the Institute are usually offered large and interdisciplinary research projects, paired with partners from other universities or research institutions, giving them the opportunity to accumulate work experience and publish in internationally renowned science journals.

The subject of renewable energy has, in the last few years, become a somewhat controversial point of discussion and this effected the revision of the EEG. Despite the fact that climate change and global warming have been unambiguously proven by this point, the positive effects of these forms of energy are still not universally agreed upon. The federal government, following the guidance of international agreements such as the 2015 Paris Climate Convention, set the goal of replacing 35% of Germany's electricity usage with energy from renewable sources by 2020. By 2019, this goal was already distinctly exceeded with a total share of 43% of electricity coming from renewables. Alongside PV and wind energy, biogas production delivers a notable ~9% of Germany's electricity. Biogas can be flexibly produced and stored in the natural gas grid as biomethane, which makes it an important cornerstone of the German power supply. Unfortunately, it is likely, if not inevitable, that the currently high level of biogas production will not be maintained. The relevant conditions of the EEG were significantly weakened during the last revisions, resulting in barely any new biogas plants being built in the past few years because these changes have made their operation economically infeasible. Only biogas plants with a maximum production of 75 kW are still able to grow due to special regulations. A special condition of these plants is an input requirement of least 80% slurry and solid manure. Plants like these, despite generating less energy than larger plants or those with higher NaWaRo-shares, offer an opportunity to utilize a larger proportion of manure produced on agricultural livestock farms in a decentralized manner, limiting uncontrolled CO_2 and ammonia emissions.

The future of the biogas sector is looking even grimmer, because the 20 year price-fixing set by the EEG is running out for a growing number of plants. This means that these plants must compete with fossil fuels at market price or participate in a tender which will cap prices at 16 ct/kWh. It will only be possible for a small number of plants to cope with this economically in the long term. The State Institute has focused its research upon questions of how these post-EEG plants can ensure long-term operational stability. Consequently, four projects were started to investigate new strategies for these biogas plants and test their feasibility. Through these projects, strategies such as the use of alternative substrates, flexible biogas production, and bioeconomic approaches to Power to Gas systems or fuel utilization are considered in process engineering and economic potential. The European Renewable Energy Directive II (RED II) creates new possibilities for the future utilization of biogas as fuel, allowing the State Institute to potentially explore these topics via research projects. Access to the university's own research biogas plant at Unterer Lindenhof

is an integral requirement of these potential projects. For their excellent coordination with the research biogas plant's team and management, the university administration and the university building department, I would like to take this opportunity to warmly and explicitly thank all the employees at the State Institute!

The young research team at the State Institute is ready and highly motivated to tackle the new challenges in the field of biogas utilization and production. By developing new strategies and transferring new knowledge into practice, we try to strengthen agricultural and biogas enterprises and secure their longevity.

We will gladly take your suggestions and welcome cooperation with research and industry partners both in Germany and worldwide.

Dr. Hans Oechsner

Head of the State Institute

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

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 in Germany and the market lead in biogas sector.

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.

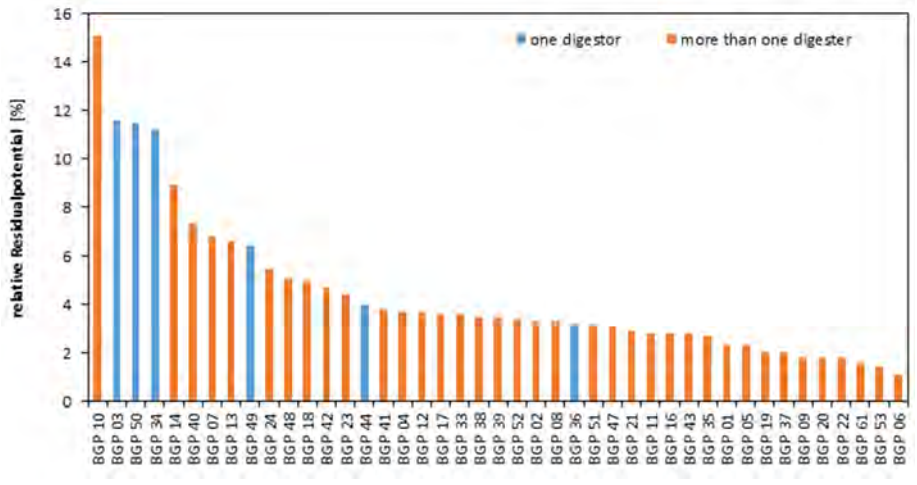
An economic, biological and technical analysis of the plants is prepared to determine their efficiency. For biological analysis, samples are taken from all containers and substrates on a monthly basis, and they are analyzed for a variety of parameters. All other analyses are based on operating data. 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 doc-toral 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 Oechsner



Relative residual potential of 45 biogas plant investigated in BMP III

Funding:
Fachagentur für Nachwachsende Rohstoffe e.V.

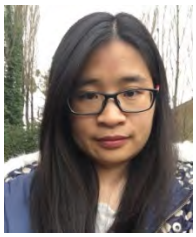
Partners:
Deutsches Biomasse Forschungszentrum (DBFZ)

Bayerische Landesanstalt für Landwirtschaft (LfL)

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

Project duration:
Jan. 2016 – Nov. 2019

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. Guo Jianbin (CAU, Peking)

Dr. Hans Oechsner

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 in 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 trial 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). According to the German BMP III samples, i.e., substrates, feeding slurry, fermentation slurry, digestate, biogas were collected and lab analysis 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 conducted. 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 biogas plant operation more profitable on the market, rather than relying only on 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 – Nov. 2019

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

Optimization of the operation and design of biogas plants for a demand-oriented, flexible, efficient and stable biogas production as a possible post-EEG strategy (OptiFlex)

The stirring system is one of the biggest consumers of power in biogas plants. Therefore, profitability strongly depends on efficient mixing of the digestate. Optimized mixing processes and, consequently, a reduction of auxiliary energy is a promising post-EEG strategy to operate biogas plants economically.

To this day, there is a lack of research on the interactions of substrates/digestate, biogas kinetics and rheological properties. Without this knowledge, a sensible optimization of the stirring system is not possible.

Thus, “OptiFlex” deals with the development and verification of rheological and kinetic models. On that basis, new agitators can be developed and tested at the full-scale research biogas plant of the University of Hohenheim. Several partners in research and industry work together to reach these goals.

Furthermore, suitable control parameters for the flexible biogas production will be identified. This, together with the optimized stirring technology, should ensure the future security of existing and newly constructed plants..

First, mixing results reveal a great saving potential concerning the power demand of the stirring system. Even small changes in the orientation of the agitators can have a strong influence on mixing times and power consumption. Additionally, the simultaneous operation of several stirrers is advantageous for reducing respectively mixing times and energy. Future CFD-simulations, laboratory experiments and full-scale trials will strengthen these results and disclose further saving potentials.

M. Sc. Benjamin Ohnmacht

M. Sc. Philipp Kress

PD Dr. Andreas Lemmer

Mixing trials at the full-scale research biogas plant of the University of Hohenheim to evaluate different mixing setups (Ohnmacht, 2018)

Funding:
Federal Ministry of Food and Agriculture (BMEL)

Fachagentur nachwachsende Rohstoffe (FNR)

Partners:
Fraunhofer Institute for Ceramic Technologies and Systems (IKTS)

German Biomass Research Centre (DBFZ)

Technische Universität Berlin (TU Berlin)

Maier Energie & Umwelt GmbH

Project duration:
Oct. 2017 – Sep. 2020

PowerLand 4.2 – Smart and Innovative Land Power Systems

M. Eng. Celina Dittmer

Dr. Johannes Krümpel

M. Sc. Philipp Kress

PD Dr. Andreas Lemmer

The future energy system has to be fundamentally transformed with an increasing percentage of renewable energies. Electricity generation from renewable sources such as wind or sun is subject to natural fluctuations. Decentralised plants with combined heat and power generation can make a significant contribution to reliably covering demand and balancing fluctuations at all times. They can be used flexibly and are very efficient. They are of particular importance as they offer the possibility to produce electricity and heat simultaneously among the renewable energies.

Powerland 4.2 is a response to the increasing complexity of the energy system by developing a fully automated control system for combined heat and power units (CHP) and biogas plants. It is designed to self-learn and forecast the energy demand of a consumption unit (e.g. a rural community) for the following 48 hours. Weekend and seasonal effects are taken into account. In addition, a forecast for electricity generation from photovoltaics and wind turbines will be prepared. The residual load should then be provided by the biogas-CHP by automatically calculating an appropriate schedule. In addition, the substrate supply for the biogas plant is triggered by an intelligent feeding management system.

Using the example of the Unterer Lindenhof as a consumption and production unit, the control system is optimised in such a way that a village can cover its electricity and heat energy requirements completely on the basis of renewable energies.

Funding:
Federal Ministry of Food and Agriculture (BMEL)

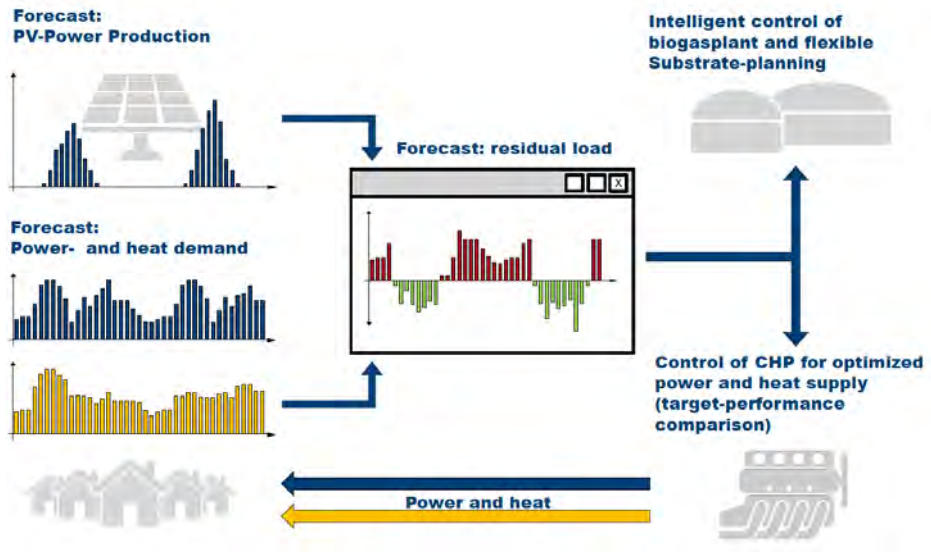
Fachagentur für Nachwachsende Rohstoffe e.V.

Partners:
Reutlingen University

Reutlinger Energiezentrum (REZ)

NOVATECH GmbH

Project duration:
Oct. 2018 – Sep. 2021



Flow chart of the system control for demand-oriented power and heat production

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)

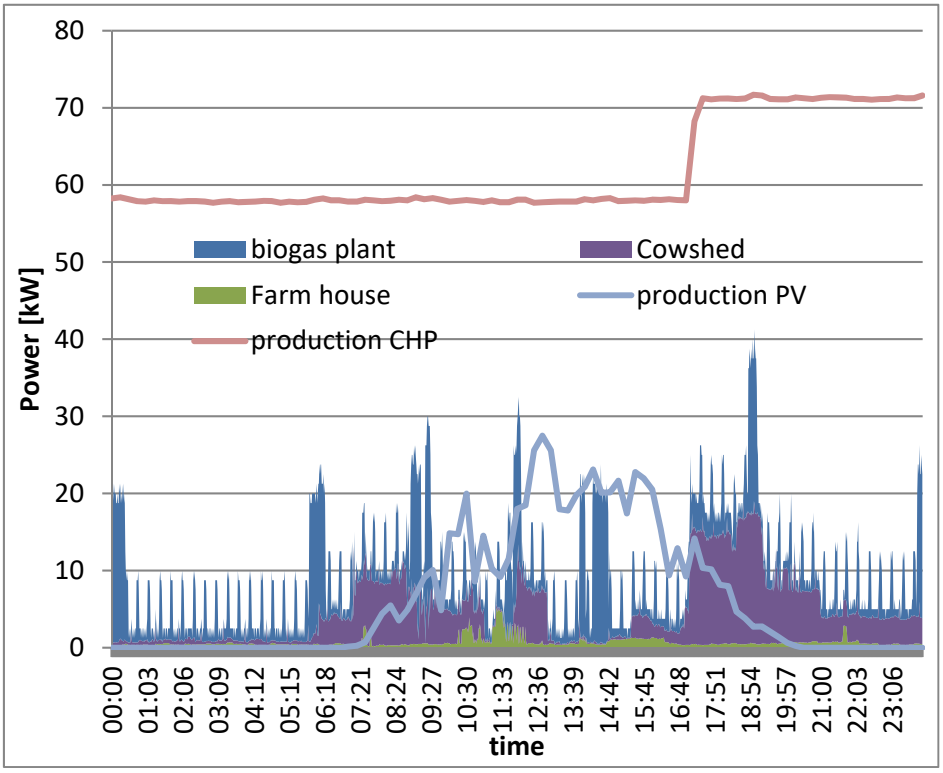
Dr. Simon Zielonka

Dr. Hans Oechsner

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.



Daily load profile of a dairy farm (Zielonka 2019)

Funding:
Federal Ministry of Food and Agriculture (BMEL)

Fachagentur für Nachwachsende Rohstoffe e.V.

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

Project duration:
Oct. 2017 – April 2020

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

Dr. Simon Zielonka

Dr. Hans Oechsner

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. In addition to the consideration of the individual plants, the contribution of the bioenergy plants for the future energy supply should also be assessed by means of modeling. Furthermore, effects on the electricity and heat supply, the reduction of greenhouse gas emissions and agriculture and forestry will be presented.

In 2019, for example, the Hohenheim Biogas Forum was held as part of the project during the Biogas Info Days 2019 in Ulm. There, practitioners were informed about the current status of post-EEG research.

Funding:
Federal Ministry of Food and Agriculture (BMEL)

Fachagentur für Nachwachsende Rohstoffe e.V.

Partners:
Deutsches Biomasse Forschungszentrum gGmbH (DBFZ)

Institut für ZukunftsEnergie- und Stoffstromsysteme gGmbH (IZES)

Helmholtz-Zentrum für Umweltforschung GmbH (UFZ)

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

Next Kraftwerke GmbH

Project duration:
Nov. 2017 – Oct. 2019

Dr. Joachim Pertagnol (IZES gGmbH) speaks on the post-EEG problem at the Hohenheim Biogas Forum during the Biogas Info Days in Ulm (Zielonka, 2019)

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

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 will be able to identify and develop suitable concepts for biogas plants.

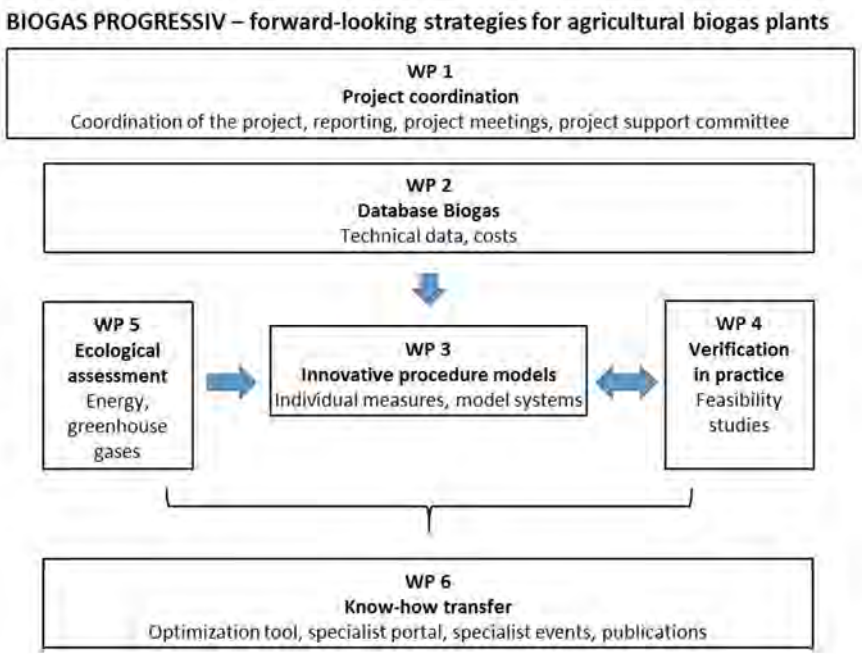
In order to achieve this goal, a comprehensive data collection will be carried out at research facilities, manufacturers of plant components and biogas plants that have already implemented innovative concepts. These data, together with the information already available to the project partners, are the 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.

Dr. Wolfgang Merkle

M. Sc. Benedikt Hülsemann

Dr. Hans Oechsner



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

Funding:
Federal Ministry of Food and Agriculture (BMEL)

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

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 at this scale, 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 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.

The results of an experiment in pressurized methane reactors show that the biological methanation of hydrogen in a two-stage system with overpressure and mesophilic temperatures up to 50°C is possible. The process temperature was increased in steps 37, 45 and 50°C. The amount of methane at 45°C was increased by 56% and at 50°C by 64% compared to the control variant without hydrogen addition and 37°C. In the 50°C variant, 62% of the added hydrogen was microbiologically converted.

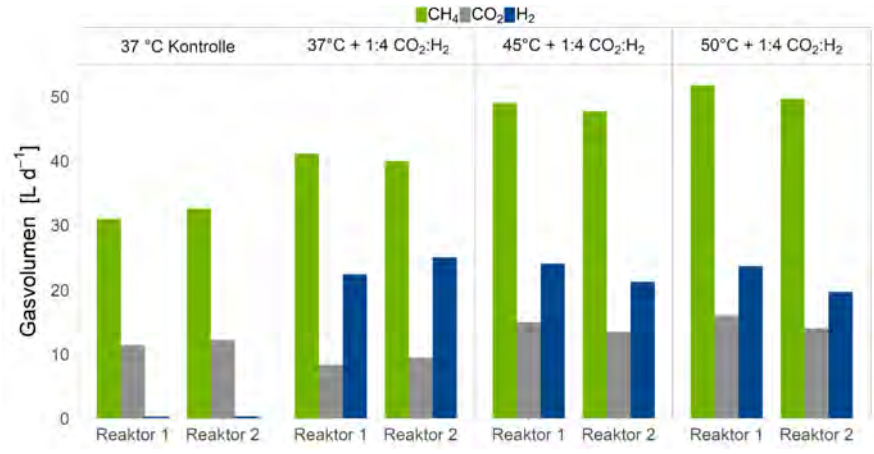
Funding:
Federal Ministry of Food and Agriculture (BMEL)

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 – March 2020



Increase of the gas volume through the biological methanation of hydrogen in a two-stage system with overpressure and mesophilic temperatures up to 50 °C (Illi, 2019)

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

M. Sc. Padma Priya Ravi

Dr. Anastasia Oskina

PD Dr. Andreas Lemmer

The aim of the joint research project is to convert biogenic waste materials into high-calorific biogas in bioelectrochemical systems. A new feature of the process is the combination of fermentative processes for breaking down solid biomass with bioelectric systems for methane production, so-called microbial fuel cells (MEC). First, hydrolysates rich in organic acids were produced from the substrate mixture at the target pH values of 5.5 and 6.0 in the hydrolysis fermenter of a two-stage system. This was treated in a cross-flow ceramic membrane filtration system and then used in the MEC.

The flat plate reactors with a total volume of 3.15 L each were designed as a continuous MEC system. They consist of an anode and a cathode compartment separated by a membrane-electrode assembly. This assembly is a composite construction of anode, anion exchange membrane and cathode materials with an increased contact area of 480 cm^2. The anode chambers of the reactors were inoculated with model microorganisms capable of transferring metabolic electrons to electrodes - *G. sulfurreducens* and *Shewanella Oneidensis* MR1. The cathode chamber was filled with effluent from a high pressure methanisation unit, enriched with a hydrogenotrophic methanogenic microorganism culture.

The anodes were adjusted to an electrical potential of 0 mV against a standard hydrogen electrode and the electrogenic biofilm was able to generate an electrical current of the order of 232.3 mA at the anode surface (current density of 4.84 A/m^2). Stable current production was achieved at a feed rate of 1.9 mL/min (30 minutes feed cycle and 2.5 hours rest). During periods of stable power production, their current density was up to 35.10±6.36 mA (0.73±0.13 A/m^2). By the bioelectrochemical activity methane and hydrogen as well as traces of oxygen, nitrogen and hydrogen sulphide could be detected inside the reactors. The methane production rate was 44.53±10.11 mL/h during periods of stable power generation.

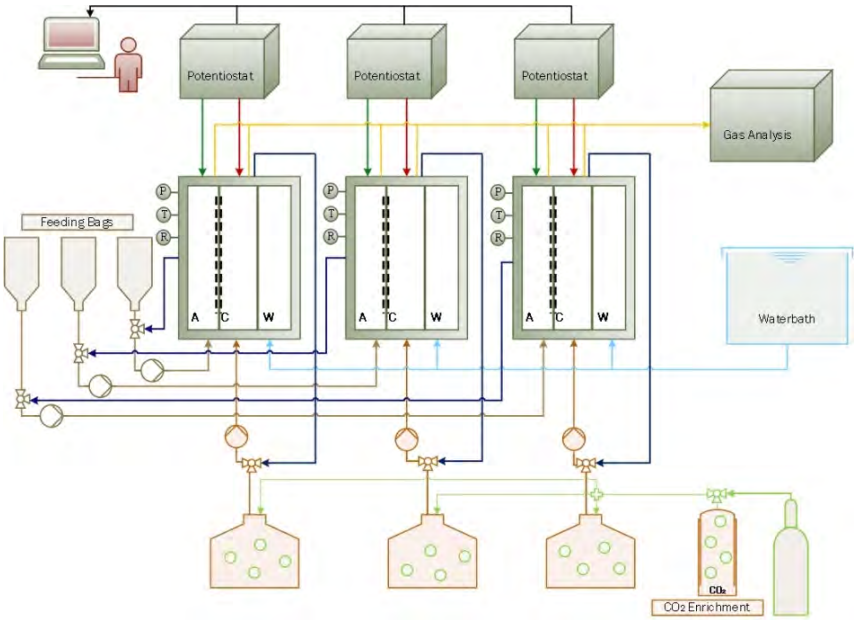


Diagram demonstrating functional units of the research plant

Funding:
Projektträger Karlsruhe – Baden Württemberg Programme

Umweltforschung Baden-Württemberg, Ministerium für Umwelt, Klima und Energie-wirtschaft

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 – March 2019

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

M. Sc. Jörg Steinbrenner

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 the material use of coproducts as chemicals with potentially high prices is 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 chemicals in the hydrolysis process, variations of process parameters like temperature, organic loading rate, pH-value and buffering capacity and a specific feed material selection, will be tested to increase the concentration of usable chemicals. The produced hydrolysate is then be treated with membranes to separate the valuable chemicals. The residue of this process is recycled in anaerobic digestion.

To optimize the yields of valuable substances, both a screening of a variety of agricultural raw materials and as well of different reaction conditions to increase the yield of valuable products will be performed. The aim is the selection of suitable substrates and appropriate hydrolysis reaction conditions.

The separation of the value-making acids via membranes is done by the Fraunhofer Institute for Chemical Technology (ICT).

In addition, the European Institute for Energy Research will do a profitability assessment and a life cycle assessment as well as developing a concept for industrial scale production.

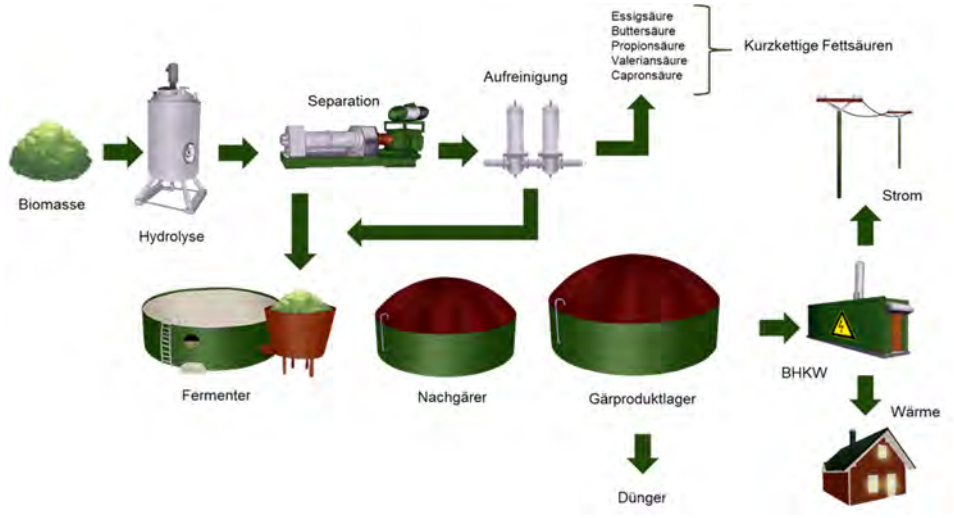
Funding:
Fachagentur Nachwachsende Rohstoffe e.V. (FNR)

Partners:
Frauenhofer Institute for Chemical Technology (ICT)

EiFER European Institute for Energy Research

Lipp GmbH

Project duration:
Sep. 2015 – June 2019



Possible process chain for the production of volatile fatty acids and biogas

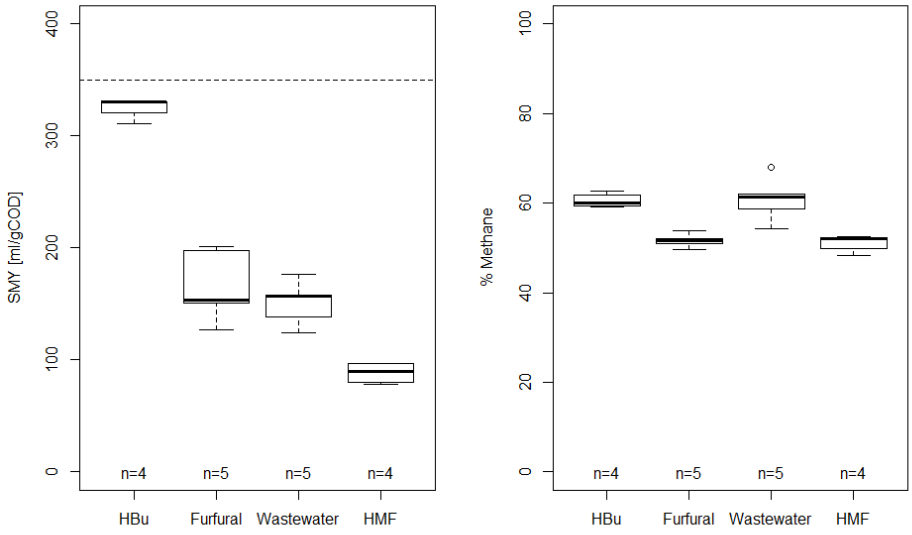
GRowing Advanced industrial Crops on marginal lands for biorEfineries (GRACE)

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 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.

Within the framework of project GRACE, the task of the State Institute for Agricultural engineering and Bioenergy will be to evaluate the biogas potential of the process wastewater generated during the Hydroxymethylfurfural (HMF) synthesis from miscanthus biomass. HMF is a platform chemical utilized by bio-based industries for the production, among others, plastic goods. The fermented residue at the end of the digestion process can be used as fertilizers. Hence closing the loop.



Preliminary results: specific methane yield (left) and methane content (right) of individual process wastewater components

M. Sc. Tahir Khan

Dr. Johannes Krümpel

PD 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

Adaptation of maize-based food-feed-energy systems to limited phosphate resources (AMAIZE – P)

M. Sc. Konstantin Dinkler

M. Sc. Bowen Li (CAU, Peking)

Dr. Guo Jianbin (CAU, Peking)

Dr. Hans Oechsner

Together with the Agricultural University of China in Beijing, the University of Hohenheim has started the international research-training group (IRTG) in November 2018. The project, funded by the German Research Foundation (DFG), has the title “Adaptation of maize-based food-feed-energy systems to limited phosphate resources”, short AMAIZE – P, and incorporates an interdisciplinary approach for the evaluation and optimization of the phosphate cycle in agriculture, human and animal alimentation and nutrient recycling. The State Institute of Agricultural Engineering is involved in the research subject 3.3. This subject aims to achieve the following:

Residues from agriculture and food production, excrements from humans and livestock and other organic wastes are often neglected resources for nutrient recovery. Anaerobic digestion can be used to partly decompose the residues and create a fertilizer with high nutrient availability. This nutrient recycling is essential for future high yield agriculture. Simultaneously an energy rich gas is generated that can be used to cover every day needs such as heating and cooking or for electricity production.

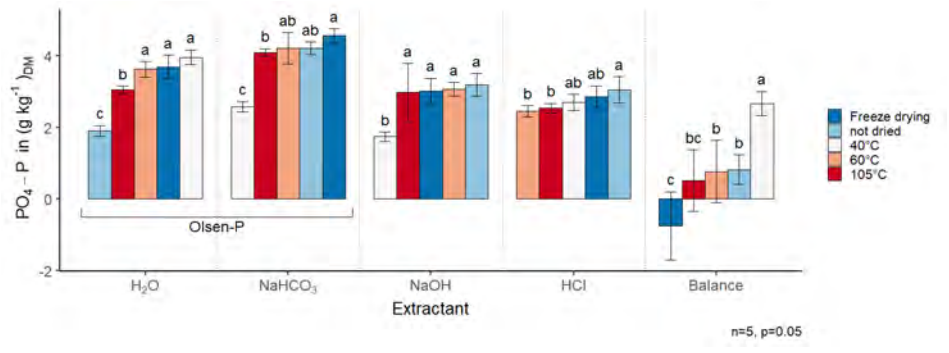
In a first step, a method for sample pretreatment and phosphate analysis was developed. To order phosphate fractions into groups, phosphate extraction was done by Hedley fractionation, an analysis method from soil science. The temperature used for drying the samples before extraction differs in literature. Therefore, an experiment with different drying temperatures was conducted to evaluate the effect of the drying temperature on the amount of extracted phosphates. The results show that drying the sample prior to extraction is not adequate for the analysis of phosphate fractions within the digester. Instead, extracting the phosphate directly from the fresh sample is more appropriate. Furthermore, the amount of Olsen-P only makes up 35% of total phosphate in the digestate.

Finanzierung:
German Research Foundation (DFG)

Partners:
China Agriculture University (CAU), Volksrepublik China

11 Institutes of the University of Hohenheim

Project duration:
Nov. 2018 – Apr. 2023



Results of the Hedley fractions of a sample from Unterer Lindenhof

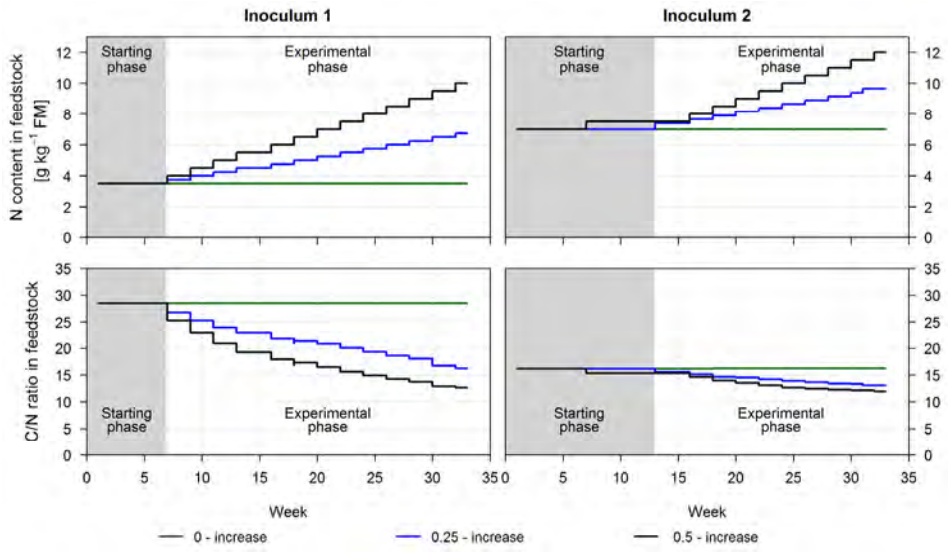
Research into the use of N-rich and lignocellulosic biomass for biogas production: methane yield potentials, process stability and nutrient management

Objective 1. Study on potential biogas and methane yields of bioenergy crops grown in Ukraine. Locally suitable varieties and different harvesting dates were investigated. The following crops were studied: soybean, sweet sorghum and sorghum hybrids, sugar beet, maize, miscanthus, switchgrass and paulownia. 98 crop samples, collected on the research fields of Agrarian Academy of Sciences of Ukraine, were analyzed by using the Hohenheim biogas yield test (HBT).

Objective 2. Utilization of protein-rich substrates, such as kitchen waste, poultry manure, microalgae, etc. may lead to high concentrations of nitrogen in the reactor during anaerobic digestion (AD). This negatively affects the process stability and efficiency due to ammonia formation. Total ammonia nitrogen is formed during the hydrolysis of proteins, urea and nucleic acids. Ammonia freely passes through the cell membranes of methanogens and causes a proton imbalance. Free ammonia changes the intracellular pH of methanogenic bacteria and inhibits specific enzymatic reactions. Therefore, high concentrations of ammonia in anaerobic reactors lead to inhibition of methanogenesis and may cause complete AD failure. Currently, many operators of biogas plants suffer from AD inhibition and methane losses when utilizing N-rich substrates.

A solution could be the acclimatization strategy by stabilizing AD and minimizing methane losses with an optimal N increase rate. The aim of this investigation was to determine the effect of different nitrogen increase rates on anaerobic digestion, in order to achieve an optimal process performance. The effect of different nitrogen increase rates in feedstock on the process stability and conversion efficiency in AD has been analysed.

Objective 3. Digestate can be commercially used as a fertilizer. The aim of the study is to obtain the highest share of nutrients in the solid fraction of digestate by using different pretreatment techniques.



Experimental procedure

M. Sc. Ievgeniia Morozova

M. Sc. Nadiia Nikulina

Dipl.-Ing. agr. Christoph Serve-Rieckmann

PD Dr. Andreas Lemmer

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 – May 2020

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

M. 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 a 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 5 m^3, with a planned electrical power of 500 W 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; especially with the cooperation partners from Algeria, Turkey and Greece
- information about biogas technology for researchers and farmers in the MENA region and dissemination through a project website, workshops and project conferences.

Dry fermentation trials were carried out on a semi-industrial scale to optimize the dry fermentation process. Municipal organic waste (brown bin) was used as a substrate. Optimal substrate mixture, process temperature, the influence of the addition of liquid inoculum were examined. Three different dry inoculum/substrate ratios were examined. During the trials, the process parameters of volatile fatty acids, DM/ oDM, pH and biogas quality and quantity were analyzed. The digestate was passed on to the Hohenheim Biogas Test.

The tunesian farm (l) und area in the farm in Tunisia to implement the pilot plant (r) (Nikulina, 2018)

Wastewater-free Environmental Campus - new technologies in building refurbishment for sustainable resource management (ReLab)

Dr. Simon Zielonka

Dr. Hans Oechsner

On the basis of a specific application object - an existing student residence at the Environmental Campus Birkenfeld - an innovative recycling concept is to be implemented into the existing building. The concept is based on the separate collection and use of wastewater and biomass potentials. For the subsequent separate collection of the waste water streams, a double inliner process will be used for the first time. This innovative process enables the separation of faecal wastewater in existing buildings. The faecal waste water, together with the organic waste produced, is fed via a vacuum system to an anaerobic utilisation for the production of biogas, while grey water is treated for different uses. This innovative approach to applied building research represents a further development of the Environmental Campus Birkenfeld towards a "wastewater-free university" in terms of sustainable regional development in the fields of energy, waste and water management. Based on previous project approaches of the IfaS, a subsequent system implementation for the existing building stock is to be developed and tested in cooperation with other scientific institutions and partners in practice.

The State Institute will carry out fermentation tests with the black water to determine its biogas yield potential under different operating conditions. In addition, the black water is tested for its suitability for fermentation in two-stage biogas systems.

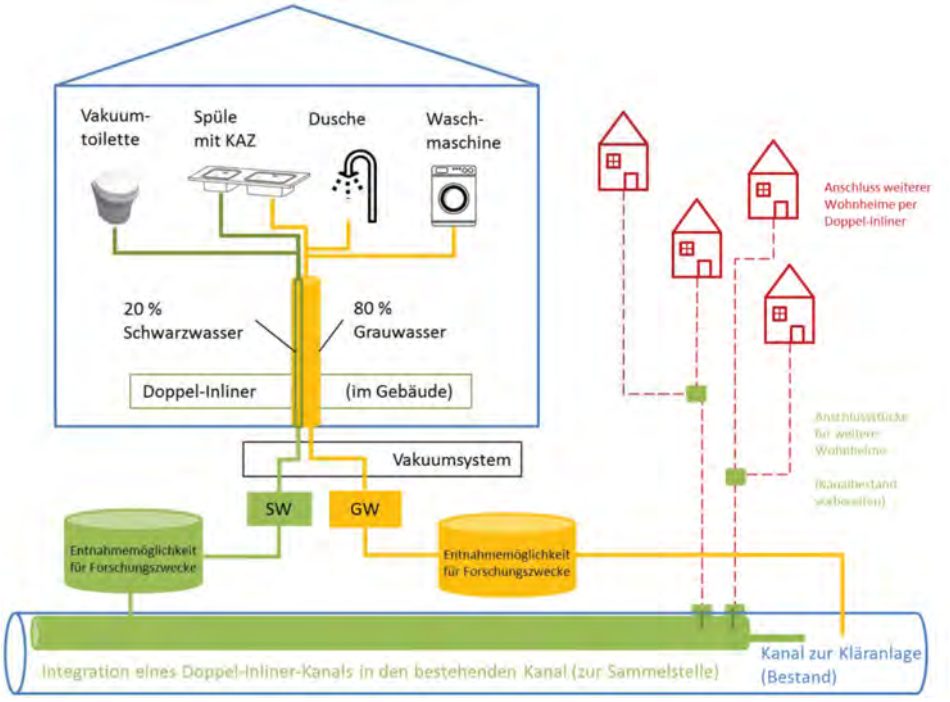


Diagram of the sanitary installation (Angilella, 2017)

Funding:
Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR)

Partners:
Trier University of Applied Sciences-Environmental Campus Birkenfeld, Institute for Applied Material Flow Management (IfaS)

Aqseptence Group GmbH

Björnsen Beratende Ingenieure GmbH

Campus Company GmbH

GEBR. RÖDERS AG

TU Kaiserslautern, Department resource efficient wastewater technologies

Project duration:
Okt. 2017 – Okt. 2020

Pro-BioLNG - Innovative process chain for resource-efficient production of Bio-LNG

Dr. sc. agr.
Wolfgang Merkle

M.Sc. Jörg
Steinbrenner

PD Dr. Andreas
Lemmer

In the course of the German government's climate protection plan 2050, greenhouse gas emissions are to be reduced by 80 to 95% by 2050 compared to the reference year 1990. Particularly in the transport sector no significant savings have been achieved so far.

For this reason, the joint project "ProBioLNG" aims to develop an innovative and highly efficient process chain for the cost-effective and regenerative production of bio-methane-based fuels at the University of Hohenheim.

Objectives

- Production of a biogas with a methane content of more than 75% by volume using two-stage pressurised fermentation.
- Coupling of the plant with biological methanisation to convert the remaining CO_2 into biomethane (power-to-gas)
- Subsequent compression or liquefaction of the gas, with reduced effort, and its use as a fuel (CNG or LNG)

The process promises to be considerably more efficient than previous methods of producing biomethane, and at lower production costs. To this end, the entire process chain is to be set up and operated as a pilot plant on a pilot scale at the Unterer Lindenhof test site of the University of Hohenheim.

Biomethane-based fuels can be used in liquefied form as Bio-LNG in heavy duty, marine, construction and agricultural machinery. The production of the innovative fuels is based in equal parts on biomass and power-to-gas processes, so that the research project makes a decisive contribution to both sector coupling and energy system transformation in the transport sector.

Funding:
Projektträger Jülich

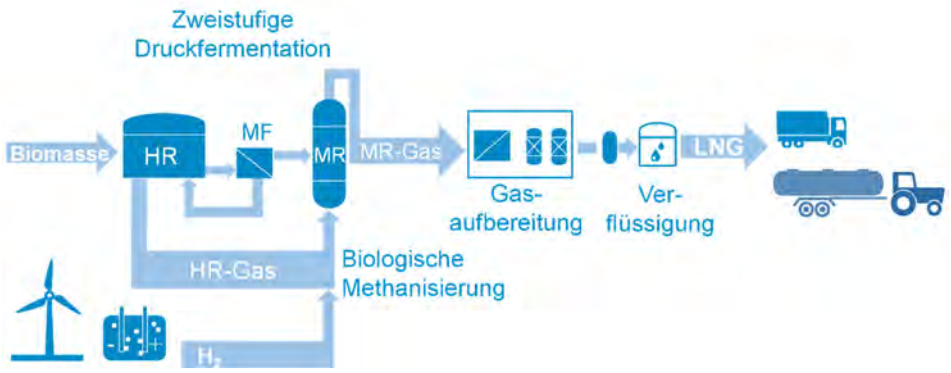
Partners:
DVGW-Forschungsstelle am Engler-Bunte-Institut

KIT Mobima

Class selbstfahrende Erntemaschinen GmbH

AirLiquide Forschung und Entwicklung GmbH

Project duration:
Sep. 2019– Aug. 2022



Possible process chain for the production of Bio-LNG

EXIST-Founder's Scholarship: development of a shredding plant for difficult substrate in biogas plants

B.Sc. Mohammad Al-Saffar

B.A. Jessica Höhmann

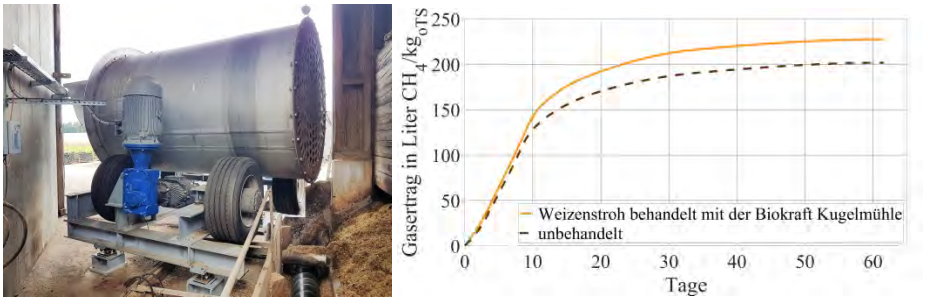
M.Sc. Fridolin Hanel

Dr. Hans Oechsner

Inspired by the idea of biogas farmer Albert Eberhart, work has been underway since 2017 on a new shredding plant for difficult substrates in biogas plants. An EXIST start-up grant for this project was successfully applied for in 2019. Previously, a prototype had already been developed by biogas plant operator Albert Eberhart from Bio-Energie Heuberg GmbH & Co. KG in cooperation with the scholarship holders. This prototype was further developed with the EXIST funds to the point of automated continuous operation. In the process, fundamental design changes were implemented, which were derived from the results of a previous conclusion work of the State Institute. The plant, christened "Biokraft Kugel¬mühle" (Biokraft ball mill), consists of a rotating hollow cylinder into which several thousand steel balls the size of tennis balls are placed. As the drums rotate, the balls are transported upwards and fall onto the substrate and other steel balls. According to the flow-through principle, the substrate to be ground flows continuously into the ball mill. The high pressures at the point of contact of colliding steel balls cause the substrate to split, breaking up the cell membranes and exposing intracellular nutrients. This results, among other things, in a faster and higher gas yield.

The scholarship also enabled the first series of tests to be carried out on the effectiveness of the developed comminution plant. For this purpose, several substrates were analysed in the Hohenheim biogas yield test. The robust and efficient shredding plant is now available on the market and will be marketed by Biokraft Energietechnik GmbH, which was founded by the scholarship holders in May 2019. The biogas plant of Bio-Energie Heuberg GmbH & Co. KG has been using more and more agricultural residues since the automated commissioning of the Biokraft ball mill in autumn 2019 and, thanks to the shredded substrate, has a lower consumption of agitation energy in the fermenter.

In addition, follow-up financing has been secured through the Agency for Renewable Resources. This will be used in future to investigate how demand-driven biogas production is possible with the aid of the Biokraft ball mill.



Prototype of the newly developed Biokraft ball mill and HBT results of wheat straw

Funding:
BMWi und Europäischer Sozialfonds

Partner:
Albert Eberhart, Bio-Energie Heuberg GmbH & Co. KG

Project duration:
March 2019 – Feb. 2020

Research biogas plant "Unterer Lindenhof"

PD Dr. Andreas Lemmer

M. Sc. Philipp Kress

On behalf of the rectorate, the state agency is responsible for the operational management and coordination of research projects at the Unterer Lindenhof biogas plant. Practical research into the production of bioenergy and the integration of biogas technology into future energy systems is becoming increasingly important. As in the past years, the research biogas plant Unterer Lindenhof was and is the central large-scale research facility for various national joint research projects.

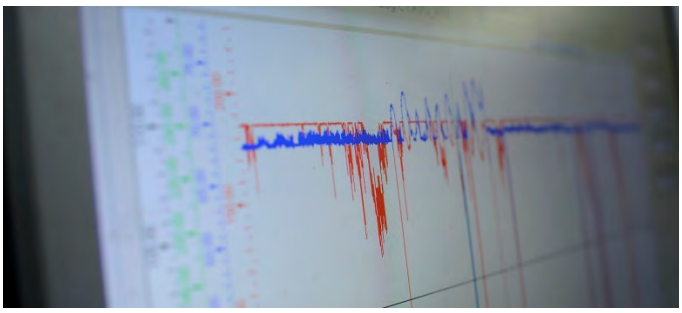
As part of the "OptiFlex" and "PowerLand 4.2" projects, both funded by the FNR, some structural changes were again made to the biogas plant in 2019. In particular, however, work has begun on extending data collection and storage in databases beyond the biogas plant.

Research is currently focusing on two topics:

- The optimisation of the operation and design of biogas plants for demand-oriented, flexible and efficient biogas production (project "OptiFlex").
- Fully automated system integration of bioenergy (project "PowerLand 4.2").

For the "PowerLand 4.2" project, in addition to the measured values previously recorded online via the plant control system of the biogas plant, in future the entire electricity and heat demand data of the "Lindenhöfe" site of the Agricultural Science Research Station will be recorded online and forecast with mathematical models for a period of 48 to 336 hours. An experimental PV system and the site's weather station will also be integrated into the system control. In this way, the site's future electricity and heat requirements and the electricity production of the PV system can not only be recorded but also predicted, so that a forward-looking, demand-oriented operation of the CHP unit to cover the residual load is possible. The research biogas plant thus takes an important step towards the decentralised provision of control energy for the future stabilisation of our electricity grids. At the research biogas plant, "AI" now meets "Big Data" in practice.

Three further major research projects with a start in 2020 were approved in 2019. This means that the research biogas plant will remain a highly topical large-scale research facility, even 12 years after commissioning.



Data collection at the control system of the research biogas plant

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

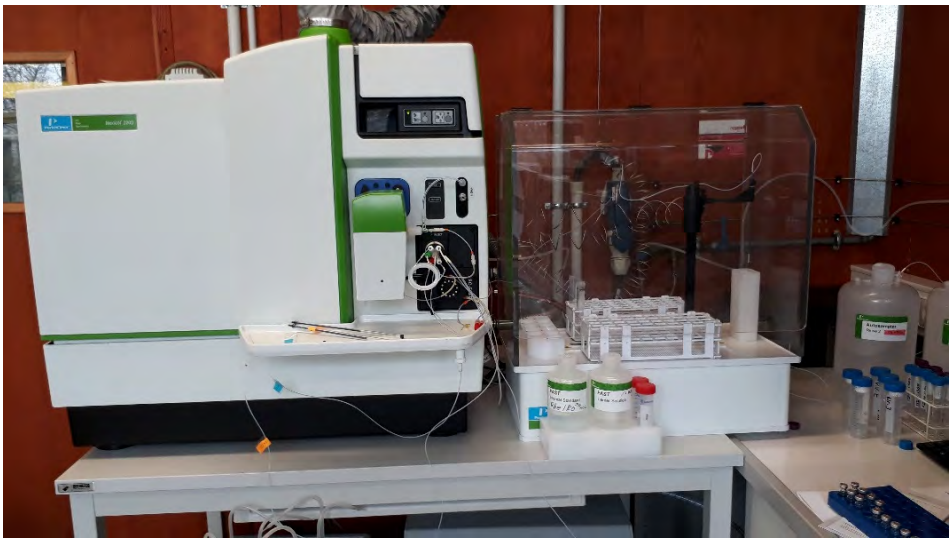
Dipl.-Biol. Annette Buschmann

Jacqueline Kindermann

In 2019, extensive chemical analyses for the process-biological assessment of fermentation processes for ensiling, biogas production or the biological production of platform chemicals were again carried out in the chemical laboratory of the State Institute as part of a wide variety of projects. Modern laboratory equipment such as a gas chromatograph (GC), a high-pressure liquid chromatograph (HPLC), a powerful analyser for the simultaneous analysis of total carbon (TC), inorganic carbon (TIC) and total nitrogen (TN) in aqueous samples plus the TC content in solid samples, a digestion and distillation system for the determination of total nitrogen and ammonium nitrogen in both aqueous and solid samples using the Kjeldahl method, etc. were used for this purpose.

The main focus of the work in 2019 was the commissioning of the mass spectrometer (ICP-MS = inductively coupled plasma mass spectrometry) installed in the laboratory in 2018 as a result of major construction work. Furthermore, the focus was on the development of methods for determining the relevant chemical elements that are important for understanding and assessing the nutrient and trace element supply of various fermentation processes.

In the meantime, the concentration of the majority of the elements of interest for the work of the State Institute, such as phosphorus (P), potassium (K), magnesium (Mg), sodium (Na), nickel (Ni), cobalt (Co), manganese (Mn), copper (Cu) and zinc (Zn) can be determined from liquid samples. The development of methods for the determination of all important elements in liquid samples is to be completed in the near future, followed by the development of methods for the corresponding determination of the same elements from solids. The sample preparation for the analysis of trace elements in the ICP-MS is carried out by microwave digestion with concentrated nitric acid using a digestion device from CEM. The digestion for the determination of liquid and solid samples is now performed without any problems.



The new ICP-MS (inductively coupled plasma mass spectrometry) (Buschmann, 2018)

Co-organized Conferences

Hohenheimer Biogasforum at the Biogas-Infotage
30.-31. January 2019, Ulm Fairs, Ulm, organised together with Renergie Allgäu e.V.

Biogastag Baden Württemberg
27. February 2019, University of Hohenheim, Stuttgart, organised together with Baden-Württemberg section of the Fachverband Biogas

ALB Fachtagung - „Ferkelerzeugung“
14. March 2019, Universität Hohenheim, Stuttgart organised together with ALB Baden-Württemberg

ALB Fachveranstaltung - „Direktvermarktung von Milch und Milchprodukten“
10. April 2019, Hohenstein-Ödenwaldstetten, organised together with ALB Baden-Württemberg

International Biogas & AD Training Course
07. – 15. May 2019, Stuttgart, ZIMT, organised together with IBBK

International Biogas & AD Training Course
24. September – 02. October 2019, Stuttgart, Uni Hohenheim, organised together with IBBK

ALB Fachgespräch - „Lagerung von Getreide und Körnerleguminosen“
28. November 2019, Burgstetten, organised together with ALB Baden-Württemberg

International Exchange

International Guest Scientists to the State Institute

Bowen Li
Provision of phosphate resources for nutrient recycling through anaerobic digestion systems.
Agricultural University of China, Faculty of Agricultural Engineering, Beijing, China

Dimitrios Mitrogiannis
Adsorption of phosphate and ammonium nitrogen from the liquid fraction of the dry fermentation digestate on mineral adsorbents (zeolite and attapulgite)
Agricultural University of Athens, Faculty of Natural Resources, Management and Agricultural Engineering, Athens, Greece

Samatcha Krungkaew
Determination of the methane yield of different parts of two banana varieties traditionally grown in Thailand using HBT
Silpakorn University, Faculty of Engineering and Industrial Technology, Nakhon Pathom, Thailand

Seda Uslu
Laboratory-scale dry fermentation experiments for process optimisation within the ERANETMED BIOGASMENA project
EGE University, Faculty of Engineering, Department of Bioengineering, Izmir, Turkey

Tsung-Hsien Chen
Study of two-stage high-pressure fermentation and exchange of experience on renewable energy.
Feng-Chia University, Faculty of Mechanical and Aerospace Engineering, University of Science and Technology, Taiwan

Xing Yu
Evaluation of the biogas cleaning technology and economic assessment.
Agricultural University of China, Faculty of Agricultural Engineering, Beijing, China

Yamina Abdoune
Training on the Hohenheim biogas test and dry fermentation technology in the framework of the ERANETMED BIOGASMENA project
Mohamed Boudiaf University of Science and Technology, Faculty of Engineering, Oran, Algeria

Scientists of the State Institute abroad

Lukas Illi
Consulting and workshop on biomethane
23.04.2019-01.05.2019, Fiep - Federação das Indústrias do Estado do Paraná, Curitiba, Brasil

University examinations 2019

Doctoral Theses

Elżbieta Joanna Kumanowska
Optimierung der Konservierung und der anaeroben Konversion von Zuckerrüben zur Nutzung in flexiblen Biogassystemen. Dissertation, University of Hohenheim.

http://opus.uni-hohenheim.de/volltexte/2020/1689/

Phillip Kress
Auswirkungen der flexiblen Biogasproduktion auf die Effizienz von landwirtschaftlichen Biogasanlagen. Dissertation, University of Hohenheim.

The doctoral thesis at the faculty of agricultural sciences are scientifically supervised by the Senior Head of the State Institute, Prof. Dr. Thomas Jungbluth.

Master Theses

Alina Röhrich
Emissionsminderung in der Milchviehhaltung durch alternative Verwertung von Gülle und Gärresten

Philipp Unfried
Ernteverfahren, Häckselqualität und Methanertrag von durchwachsener Silphie (Silphium perfoliatum L.)

Bachelor Theses

Adrian Kronawitter
Vergleichende Untersuchungen zu unterschiedlichen Eintragssystemen von Wasserstoff in die biologische in-situ Methanisierung

Publications 2019

Peer-reviewed

Angelidaki, I., Xie, L., Luo, G., Zhang, Y., Oechsner, H., Lemmer, A., Munoz, R., Kougias, P.G.
Biogas upgrading: Current and emerging technologies. (2019) In: Pandey, A., Larroche, C., Dussap, C.-G., Gnansounou, E., Khanal, S.K., Ricke, S.: Biofuels: Alternative feedstocks and conversion processes for the production of liquid and gaseous biofuels. (2019) Biomass, Biofuels, Biochemicals: Biofuels: Alternative Feedstocks and Conversion Processes for the Production of Liquid and Gaseous Biofuels, pp. 817-843. DOI: 10.1016/B978-0-12-816856-1.00033-6. Elsevier. ISBN: 9780128168561

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Investigating flexible feeding effects on the biogas quality in full-scale anaerobic digestion by high resolution, photoacoustic-based NDIR sensing. (2019) Engineering in Life Sciences, 19 (10), pp. 700-710. DOI: 10.1002/elsc.201900046

Chala, B., Oechsner, H., Müller, J.
Introducing temperature as variable parameter into kinetic models for anaerobic fermentation of coffee husk, pulp and mucilage. (2019) Applied Sciences (Switzerland), 9 (3), art. no. 412, DOI: 10.3390/app9030412

Jänisch, T., Reinhardt, S., Pohsner, U., Böringer, S., Bolduan, R., Steinbrenner, J., Oechsner, H.
Separation of volatile fatty acids from biogas plant hydrolysates. (2019) Separation and Purification Technology, 223, pp. 264-273. DOI: 10.1016/j.seppur.2019.04.066

Kumanowska, E., Zielonka, S., Oechsner, H.
Sickersaftbildung aus der Silage von Zuckerrübenschnitzeln. (2019) Landtechnik, 74(3). DOI: 10.15150/lt.2019.3203

Lansing, S., Hülsemann, B., Choudhury, A., Schueler, J., Lisboa, M.S., Oechsner, H.
Food waste co-digestion in Germany and the United States: From lab to full-scale systems. (2019) Resources, Conservation and Recycling, 148, pp. 104-113. DOI: 10.1016/j.resconrec.2019.05.014

Ohnmacht, B., Kress, P., Parrales, J. K. H., Lemmer, A.
Untersuchung der internen, biologischen Entschwefelung mittels Dosierung von Umgebungsluft. (2019) Landtechnik, 74(6). DOI: 10.15150/lt.2019.3224

Ravi, P.P., Merkle, W., Tuczinski, M., Saravia, F., Horn, H., Lemmer, A.
Integration of membrane filtration in two-stage anaerobic digestion system: Specific methane yield potentials of hydrolysate and permeate. (2019) Bioresource Technology, 275, pp. 138-144. DOI: 10.1016/j.biortech.2018.12.043

Steinbach, D., Wüst, D., Zielonka, S., Krümpel, J., Munder, S., Pagel, M., Kruse, A.
Steam explosion conditions highly influence the biogas yield of rice straw. (2019) Molecules, 24(19), art. no. 3492, DOI: 10.3390/molecules24193492

Steinbrenner, J., Nägele, H.-J., Buschmann, A., Hülsemann, B., Oechsner, H.
Testing different ensiling parameters to increase butyric acid concentration for maize silage, followed by silage separation and methane yield potential of separated solids residues. (2019) Bioresource Technology Reports, 7, art. no. 100193, DOI: 10.1016/j.biteb.2019.100193

Stökle, K., Hülsemann, B., Steinbach, D., Cao, Z., Oechsner, H., Kruse, A.
A biorefinery concept using forced chicory roots for the production of biogas, hydrochar, and platform chemicals. (2019) Biomass Conversion and Biorefinery, DOI: 10.1007/s13399-019-00527-w

Ullrich, T., Lemmer, A.
Performance enhancement of biological methanation with trickle bed reactors by liquid flow modulation. (2019) GCB Bioenergy, 11(1), pp. 63-71. DOI: 10.1111/gcbb.12547

Conference proceedings posts

Hülsemann, B., Lansing, S., Choudhury, A., Schueler, J., Sol Lisboa, M., Oechsner H.
Lebensmittelvergärung in Deutschland und den USA. In: Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL): Biogas in der Landwirtschaft – Stand und Perspektiven. pp. 315-316. KTBL-Schrift 517. FNR/KTBL-Kongress, Leipzig, 09.-10.09.2019

Hülsemann, B., Zhou, L., Oechsner H.
Biogas measurement program – Seasonal Differences in Residual Methane Potential of Digestate. IV. CMP International Conference on Monitoring & Process Control of Anaerobic Digestion Plants, Leipzig, 26.-27.03.2019

Kumanowska, E., Zielonka, S., Lemmer, A., Oechsner, H.
Optimierung der Konservierung und der anaeroben Konversion von Zuckerrüben zur Nutzung in flexiblen Biogassystemen. In: Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL): Biogas in der Landwirtschaft – Stand und Perspektiven. pp. 91-103. KTBL-Schrift 517. FNR/KTBL-Kongress, Leipzig, 09.-10.09.2019

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Energetische Untersuchungen zur Rührtechnik in einer Praxisanlage. In: Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL): Biogas in der Landwirtschaft – Stand und Perspektiven. pp. 361-362. KTBL-Schrift 517. FNR/KTBL-Kongress, Leipzig, 09.-10.09.2019

Merkle, W., Oechsner, H., Paterson, M., Wirth, B.
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Committee work

- Bioresource Technology: Member of the editorial board
- MDPI: Special Issue Editor "Renewable Energy in Agriculture”
- KTBL - Presidency "Working Group Energy”
- KTBL - Working group "Interlaboratory comparisons”
- KTBL - Working group "sustainable biogas production”
- KTBL - Working group "Gastight liquid manure storage”
- KTBL - Working group "Gas yields”
- KTBL - Working group "Slurry digestion”
- VDI Guideline 4630 - Scientific Committee
- VDLUFA - Methods Commission Biogas yield, residual gas potential
- DLG - Examination Commission "Separator”
- VERA - International VERA Commission for Manure Separation
- BCN - Biogas Competence Network e.V.
- International Working Group "Method for Determining Biogas Yield”
- Various conference committees (e.g. VDI, KTBL, FNR, FV-Biogas, Progress in Biogas, Uni Stuttgart, Eranetmed, Doctoral Colloquium)
- Project advisory boards (Bio2020Plus, OptiSys, Subeval)

The staff of the State Institute of Agricultural Engineering & Bioenergy

Director

Dr. Hans Oechsner

Senior Director

Prof. Dr. Joachim Müller

Deputy Director

PD Dr. Andreas Lemmer

Secretary

Margit Andratschke

Scientific Staff

Dr. Simon Zielonka

Dr. Johannes Krümpel

Dr. Wolfgang Merkle

Bilhate Chala

Doctoral Candidates

Benedikt Hülsemann

Benjamin Ohnmacht

Celina Dittmer

Elzbieta Kumanowska

Ievgeniia Morozova

Jörg Steinbrenner

Konstantin Dinkler

Lijun Zhou

Lukas Illi

Padma Priya Ravi

Philipp Kress

Muhammad Tahir Khan

Technical Staff and Project Assistants

Analytical laboratory

Annette Buschmann

Jaqueline Kindermann

Test Engineers

Christof Serve-Rieckmann

Daniel Riehle

Saliha Ezgi Küver

Dr. Anastasia Oskina

Project Assistent

Nadiia Nikulina

The State Institute of Agricultural Engineering & Bioenergy

Director
Dr. sc. agr. Hans Oechsner

Senior Director
Prof. Dr. sc. agr. Joachim Müller

Deputy Director
PD Dr. sc. agr. Andreas Lemmer

Secretary
Margit Andratschke

Scientific Staff, Post-Docs
Dr. sc. agr. Simon Zielonka (Post-Doc)

Dr. sc. agr. Johannes Krümpel (Post-Doc)

Dr. sc. agr. Wolfgang Merkle (Post-Doc)

M.Sc. Bilhate Chala

Doctoral Candidates
M.Sc. Benedikt Hülsemann

M.Sc. Benjamin Ohnmacht

M.Sc. Celina Dittmer

M.Sc. Elzbieta Kumanowska

M.Sc. Ievgeniia Morozova

M.Sc. Jörg Steinbrenner

M.Sc. Konstantin Dinkler

M.Sc. Lijun Zhou

M.Sc. Lukas Illi

M.Sc. Muhammad Tahir Khan

M.Sc. Padma Priya Ravi

M.Sc. Philipp Kress

Doctoral theses are under the scientific supervision of:

- Prof. Dr. Thomas Jungbluth,
- Prof. Dr. Joachim Müller,
- PD Dr. Andreas Lemmer

Technical Staff and Project Assistants
Dipl.-Ing. agr. Christof Serve-Rieckmann

B.Sc. Daniel Riehle

B.Sc. Saliha Ezgi Küver,

Dr. Anastasia Oskina

M.Sc. Nadiia Nikulina

CT Assistants
Dipl.-Biol. Annette Buschmann

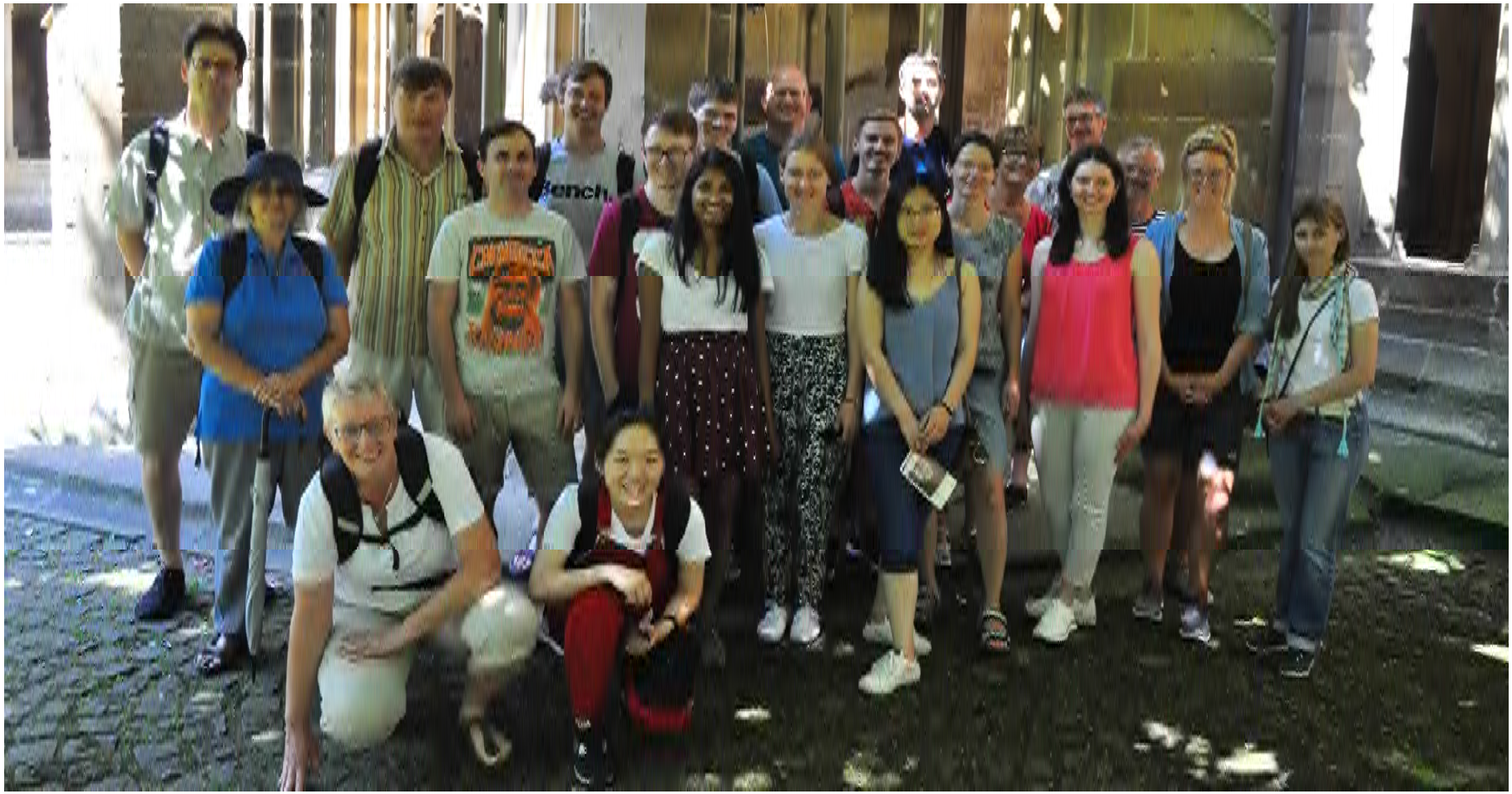
Jacqueline Kindermann

Visiting Address:
Universität Hohenheim
Landesanstalt für Agrartechnik und Bioenergie
Garbenstraße 9
70599 Stuttgart

Postal Address:
Universität Hohenheim (740)
70593 Stuttgart

Tel.: +49 (0)711 459-22683
Fax.: +49 (0)711 459-22111

Email: la740@uni-hohenheim.de
Homepage: www.uni-hohenheim.de/labioenergie



Left to right:

Dr. Simon Zielonka, Margit Andratschke, Dr. Hans Oechsner, Lukas Illi, Dr. Wolfgang Merkle, Jörg Steinbrenner, Padma Priya Ravi, Benedikt Hülsemann, Philipp Kress, Nadiia Nikulina, Konstantin Dinkler, Lijun Zhou, Dimitrios Mitrogiannis, Jacqueline Kindermann, Elke Weiß, Ievgeniia Morozova, PD Dr. Andreas Lemmer, Christof Serve-Rieckmann, Celina Dittmer, Dr. Anastasia Oskina

Hockend: Annette Buschmann, Bowen Li

Es fehlen: Prof, Dr. Joachim Müller, Dr. Johannes Krümpel, Bilhate Chala, Elzbieta Kumanowska, Benjamin Ohnmacht, Muhammad Tahir Khan, Daniel Riehle, Saliha Ezgi Küver