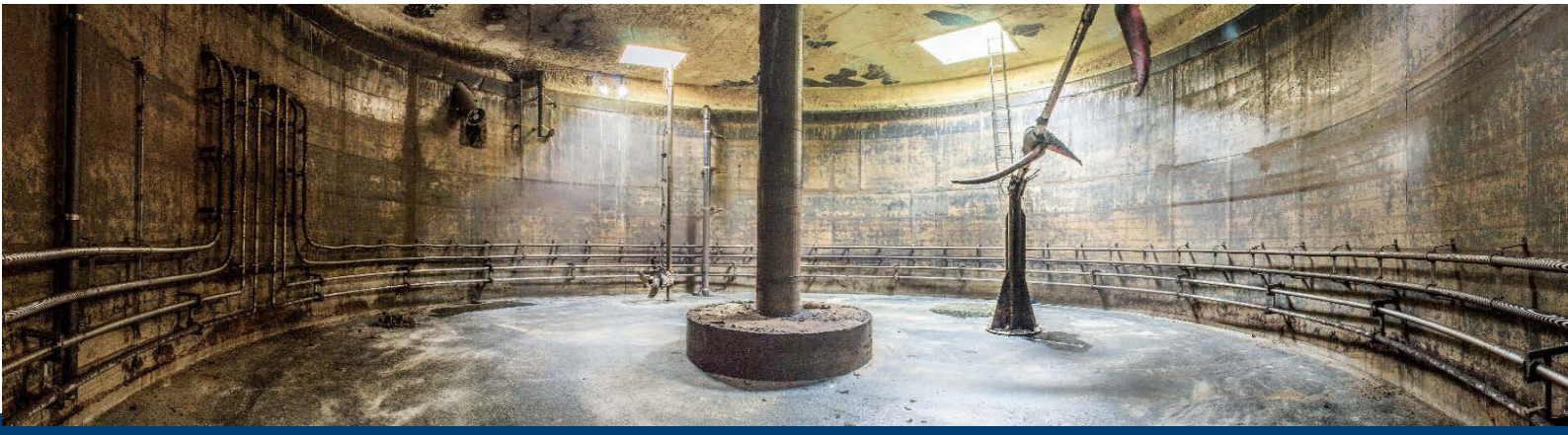
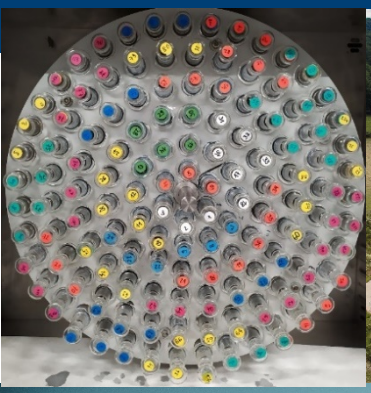
UNIVERSITÄT HOHENHEIM

LANDESANSTALT für Agrartechnik & Bioenergie

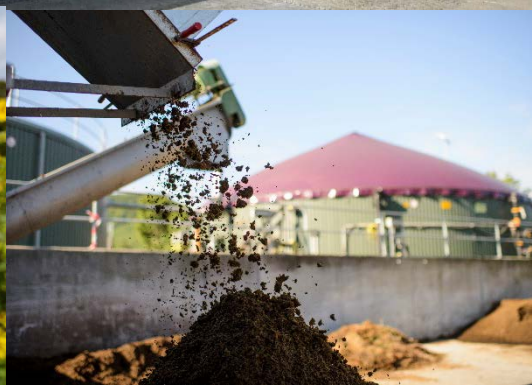


Annual Report 2021

State Institute of Agricultural Engineering and Bioenergy





The State Institute of Agricultural Engineering & Bioenergy

The State Institute for Agricultural Engineering and Bioenergy is a special institution of the University of Hohenheim and has the following tasks according to its statutes:
- Practical research

- Special consulting for agriculture in Baden-Württemberg

- Technical consulting for agricultural commercial and industrial enterprises

- Further training of the teaching and advisory staff of the agricultural administration with regard to the state of the art and new experimental results

Since the Landesanstalt has dedicated itself for many years to subject areas such as biogas production and questions regarding bio-economy, the above-mentioned range of tasks has expanded in recent years in the direction of university teaching. Due to the habilitation of PD Dr. Andreas Lemmer, some of the teaching tasks, especially the doctoral supervision, are now directly fulfilled and others are carried out together with the head of the state institute, Prof. Joachim Müller. The teaching topic of biogas has become an integral part of the curricula of NAWARO studies and agricultural sciences. Students complete their bachelor and master theses within the framework of research projects and gain valuable research experience while working as research assistants at the State Institute. For doctoral students employed at the State Institute, the research projects, which are large and interdisciplinary with partners from other universities and research institutions, offer the opportunity to gain experience in scientific work and to publish their results through publications in renowned international scientific journals.

The second pandemic year still had a massive impact on our work. Teaching was conducted almost exclusively through online programs. After the experience of the summer semester 2020, the presentation format of the courses was further optimized to give participants the chance for improved collaboration and exchange via online groups. This improvement in communication between participants was particularly successful in the biogas planning event. The seminars of the State Institute office staff and the communication on projects and project proposals had to take place via web conferences. Direct contact was further reduced via home offices, so that usually only one person could work in each office. The university's guidelines for dealing with Covid-19 were fully complied with. Thanks to the availability of vaccines, the situation improved during the year. The Covid-19 pandemic had a significant impact on international contacts and exchanges of scientists. Our international congress "Progress in Biogas V", originally scheduled for September 2020, had to be postponed to 2021. In order to also allow an international audience to participate in the congress, it was held entirely online. The time difference was a particular challenge. However, it proved to be a good decision to proceed in this way, as more than 160 scientists from 22 countries applied to speak. Together with the main organizer IBBK we managed to hold the event in three sessions in parallel. 86 oral presentations, 17 short presentations and 30 posters could be presented. Selected papers will be printed in a special issue of the scientific journal Bioresource Technology in 2022.

The staff of the State Institue is very active in preparing manuscripts for publishing of the excellent results in international scientific journals. Thus, the international importance of the State Institue is growing and requests for collaboration, exchange of scientists or joint application for research projects are increasing. In addition to these publications, publications are also made in agricultural weeklies or in national conferences for farmers and operators of biogas plants. In this way, the important findings from the research activities can be communicated to the users in a practical and fast way and implemented there.

At the end of 2020, a new version of the Renewable Energy Sources Act (EEG) was drafted, which is expected to bring certain improvements for biogas operators. In combination with the requirements of the European Renewable Energy Directive II (RED II), there are further perspectives for companies that will deal with the production of fuel in the future. The Sate Institue project being worked on in this regard, with the construction of a pilot plant for LNG and CNG production, as well as the investigations into sensor technology, modeling and flexible biogas production at the research biogas plant at the "Unterer Lindenhof", offer new insights and development opportunities for practical

applications. The model project of the State Institute for the use of a regular bus with biogas LNG will provide important insights for interested parties. The project "Bundesmessprogramm Biogas III" was completed by comprehensive report volumes on the 61 investigated practical plants at the FNR. Thus, the status quo of biogas technology has been recorded and serves as a basis for new approaches to solutions. The EEG has now been law for more than 20 years and more and more biogas plants are losing their economic viability with the expiration of the 20-year commitment period of the EEG compensation. Several research projects have sought solutions for these plants. Among other things, feasibility studies for model farms were prepared in a post-EEG project of the State Institue with the KTBL. A model calculator is available on the Internet at KTBL and allows calculations to be made for the biogas farms in order to assess possible solutions.

Since 2020, the state government has issued new calls for projects in the field of "bioeconomy", in which the State Institute also participated. In the research projects approved for this purpose, the production of fibers from permanent crops (e.g. silphia) or from by-products (e.g. hop grubbings), for example for the production of paper, played a particularly important role and is being investigated both at laboratory level and on a practical scale. Their combination with biogas production allows us to think about new digester designs in practice. The growing equipment of our special laboratories for biogas production, substrate separation and chemical analysis and the knowledge of the staff working there provide an excellent basis for carrying out the analyses required in the research area quickly and accurately. The equipment was further improved in the year under review through the use of special microscopes, innovative analysis technology and evaluation software, including the use of databases, and improved biogas laboratory fermenters, allowing a more refined evaluation of test results.

Only through the great commitment and the resulting excellent cooperation with the management and the team of the research station the successful development and testing of completely new technological approaches is possible on a practical scale. Special thanks go to the university management and the university administration as well as the university construction office for their excellent and usually quick support during the implementation of complex reconstruction measures!

The young research team of the State Institute continues to face the new challenges in the environment of bioeconomy, biogas production and utilization willingly and with highest motivation. We try to strengthen and secure the situation of farms and biogas plant operators in rural areas in the long term by developing new strategies and transferring findings into practice. In doing so, we are also focusing on important developments for society as a whole at a time when there is an obvious need for rethinking in the energy sector. I would like to express my sincere thanks to all employees, scientific assistants and students of the State Institute for their extraordinary commitment!

In order to further develop innovative ideas, we are happy to take up your suggestions and are open to cooperative partnerships with research and industrial partners in Germany and worldwide.

Dr. Hans Oechsner

Head of the State Institue

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 for Agricultural Engineering and Bioenergy, the laboratory equipment has been continuously expanded in recent years and, in parallel, new methods have been developed for the chemical analysis of a wide range of parameters such as volatile fatty acids, sugars, alcohols, macro- and micronutrients, heavy metals, etc. The results of these analyses lead to a better understanding of process biological fermentation processes in ensilage processes and/or to the optimization of biological production of platform chemicals within the scope of various projects. All analysis results lead to a better understanding of process-biological fermentation processes in ensiling operations, to the optimization of biogas production and/or to the biological production of platform chemicals within the scope of a wide variety of projects. An overview of selected analyses is given in the following table

Parameter	Methods and device(s)	Description
volatile fatty acids	Capillary gas chromatography (GC) - GC of the company Varian (type: CP-3800) with FID detector and capillary column CP 7777 of the company Varian (50m length, 0.32 µm diameter, 0.25mm occupancy	Qualification and quantification of lower carbonic acids from liquid and solid samples; e.g.: Acetic, propionic, n- and iso- butyric, n- and iso- valeric, caproic acids.
Alcohols, sugar	High pressure liquid chromatography (HPLC) - instrument from Bischoff with RI detector and a. BioRad Aminex HPLC column HPX-87H (7.8 x300mm; part. size: 5.0µm) and BioRad precolumn HPX - 87H b. Hyperchrome HPLC column Repro-Gel Ca (300 x 8.0mm; part. Size: 9.0µm)	Qualification and quantification of various acids, sugars and alcohols. e.g.: DL-lactic acid, sucrose, fructose, glucose, ethanol, 1,2-propanediol and mannitol.
TC / TN	Thermo-catalytic high-temperature oxidation with multi N/C 2100 S of the company Analytik Jena	Quantification of the inorganic carbon content and the total carbon and nitrogen content of liquid samples; quantification of the total carbon content of solids.
ICP-MS	Mass spectrometry - ICP-MS NexION 2000 from the company Perkin Elmer	Physical standard method for the qualitative and quantitative determination of elemental contents. Inorganic elemental analysis for mass spectrometric trace analysis of e.g. heavy metals and micronutrients.
CSB (Chemical oxygen demand)	Photometry - Cell test LCK 014, 514 from Dr. Lange, Thermostat LT 200 - Hach Lange; LASA 20 - Sensor Array Photometer from Dr. Lange	Parameter for the degree of organic contamination of a liquid, determined according to a standardized method.
FOS / TAC	Titration with tiamo 1.2, Titrando and Sample processor from Metrohm	Parameter for the determination of the ratio of volatile organic acids (FOS) to the acid binding capacity of the sample (TAC)
NH_4-N (Ammonium nitrogen) NH_4^+ (Ammonium)	Distillation and titration with Vapodest 50s from Gerhardt	Ammonia (NH_3) und ammonium (NH_4^+) are in equilibrium ($NH_3+H_2O \Leftrightarrow NH_4^+ + OH^-$). They are measured together during analysis (distillation followed by titration). The result can be expressed as ammonium concentration or - related to nitrogen only - as ammonium nitrogen.
TKN	Acid digestion with Gerhardt digestion block with turbo suction and subsequent distillation and titration with Vapodest 50s from Gerhardt.	Sum of organically bound nitrogen and NH_4-N as a measure of non-oxidized nitrogen. In contrast to the TN determination (see above), this method does not measure nitrogen from nitrite and nitrate compounds.

System-suitable balancing of seasonal fluctuations in energy demand through seasonally flexible biogas production using the practical example of the management of extensive and biotope grassland; Subproject 2: Substrate preparation, storage and kinetics (BioSaiFle)

M.Sc. Christina Brandhorst

PD Dr. Andreas Lemmer

When considering future biogas production, research into the use of residual materials, the flexibility of feedstocks, and energy production in line with demand are increasingly becoming the focus of public attention. Both the feed-in of fluctuating renewable energies (fRE) and the electricity and heat demand have a seasonal profile due to changing weather conditions. This profile can be provided analogously by seasonally adapted biogas plants (BGP). Especially for BGPs that are connected to the heating grid, the concept of seasonalization would be a perspective for the future, the practicability of which we want to support throughout Germany.

Since there are limits to the gas storage capacity of a BGP, energy storage is provided by biomass. In this case, the use of common energy-rich substrates, such as silage and grain, is postponed to winter and the plant output in summer is reduced due to the reduced gas production when using a substrate that is difficult to decompose. Against this background, this research project will investigate the suitability of clippings from extensive or biotope grassland (e.g. lowland hay meadows) as a promising residual material for the seasonal flexibilization (seasonalization) of BGP. Clippings from conservation areas have a good carbon footprint and do not compete for land. Since the sites depend on regular biomass extraction to ensure or improve their conservation status, energy use would thus contribute to their conservation and, at the same time, to nature-compatible biogas production.

In the second year of the project, different harvesting methods for salvaging cuttings from meadow orchards were tested and these were monitored within the framework of a working time study. Furthermore, storage and mechanical pre-treatment tests were carried out for the handling of the cuttings at the research biogas plant. With the help of these investigations, recommendations for action can be derived for the energetic use of the undergrowth of orchard meadows.

In addition to the example from Baden-Württemberg, the operational concept of seasonalization is also being examined for natural areas in Brandenburg. In addition to the practice-oriented question, seasonalization is considered in detail ecologically, economically and at the system level, so that a transfer potential for the remaining federal states can be determined.

Funding:
Bundesministerium für Ernährung und Landwirtschaft (BMEL)

Fachagentur Nachwachsende Rohstoffe e.V. (FNR)

Partners:
Universität Stuttgart, Institut für Energiewirtschaft und Rationelle Energieanwendung (IER)
Leibniz-Institut für Agrartechnik und Bioökonomie e.V. (ATB)
Potsdam
Landkreis / Landratsamt Reutlingen
Landschafts-erhaltungsverband im Landkreis Reutlingen e.V.
Obst- und Gartenbauverein unter Achalm e.V.
Landschafts-Förderverein Nuthe-Nieplitz-Niederung e.V.

Energiegenossenschaft Gussenstadt eG (EGG)

Duration:
Jan. 2020 – Dec. 2022

Use of the "Grashopper" mounted mower from Amazone in the orchard meadows in the district of Reutlingen

Development and testing of sensor-based stirring systems in biogas plants to increase efficiency and process stability in load-flexible and demand-oriented biogas production (Sens-O-Mix)

Dipl.-Ing. Benjamin Ohnmacht

Dr. Johannes Krümpel

PD Dr. Andreas Lemmer

Efficient stirring in biogas plants is still a challenge: On the one hand, the material in the fermenter must be stirred to distribute the added substrates in the tank and to ensure a stable fermentation process. On the other hand, intensive agitation leads to high internal power consumption and impairs methane production due to mechanical stress. This dichotomy is further aggravated with regard to flexible biogas production when large amounts of substrates are added to the digester within a short period of time.

So far, no practicable technical solution is available that can reliably and automatically detect the stirring requirement in the tank and derive the optimum stirring settings. Decisions to date have been made mainly on the basis of experience and by looking at the digestate surface.

Building on the "OptiFlex" and "FlexFeed" projects, the digesate rheology is being characterized in greater depth in "Sens-O-Mix", and the mixing is being optimized in laboratory and by means of CFD. Within the project, one of the two fermenters of the research biogas plant of the University of Hohenheim at Unterer Lindenhof was equipped with extensive sensor technology to determine the stirring requirements of the plant during constant and load-flexible operation. Self-learning methods are used to identify suitable parameters for the stirrer control and to quantify the influence of the pozess parameters on the methane yield. The existing models for the prediction of (flexible) biogas production are to be further developed and coupled with the measured variables obtained. The simulations and models will be validated and the stirrer control and the overall process will be evaluated by practical trials at Unterer Lindenhof.

After installation of the sensors, commissioning and initial tests on load-flexible operation at different stirrer settings are currently taking place.

The project is coordinated by Fraunhofer IKTS. The state institute is concerned with the installation and validation of suitable measurement technology as well as with the practical implementation of stirrer control and load-flexible operation.

Modification measures in the fermenter of the research biogas plant for sensor-based detection of the stirring requirement (2021, University of Hohenheim).

Funding:
Bundesministerium für Ernährung und Land-wirtschaft (BMEL)

Fachagentur Nach-wachsende Rohstoffe e.V. (FNR)

Partners:
Deutsches Biomasseforschungszentrum (DBFZ)
Fraunhofer-Institut für Keramische Technologien und Systeme (IKTS)
Technische Universität Berlin (TU Berlin)
Repowering Technik Ost GmbH (RTO)
Helmholtz-Zentrum Dresden-Rossendorf (HZDR)

Duration:
May 2020 – April 2023

Optimierung des Betriebs und Designs von Biogasanlagen für eine bedarfsgerechte, flexibilisierte und effiziente Biogasproduktion unter Berücksichtigung der Prozessstabilität (OptiFlex)

Dipl.-Ing. Benjamin Ohnmacht

PD Dr. Andreas Lemmer

In biogas plants, the agitators are often the largest consumers of electricity. The economic efficiency of a plant is thus essentially based on the efficient mixing of the fermentation substrate. Reducing the required stirring energy by optimizing the mixing processes is therefore promising for operating biogas plants economically even after the EEG period. In the "OptiFlex" project, partners from various research institutions and from industry are therefore working together to develop and verify models of the flow behavior of the fermentation substrate and of the biogas formation kinetics.

Based on the rheological knowledge gained, new agitators were developed within the project and tested at the research biogas plant. In addition, those variables were specifically identified that are suitable for controlling biogas production with a flexible reactor feed. This, together with the optimized agitator technology, should ensure the future safety of existing and newly constructed plants.

Even small changes in the spatial arrangement of the agitators can have a major impact on the necessary agitation times and power consumption. The simultaneous use of several agitators has also proven to be a strong advantage compared to the use of a single agitator. By reducing the agitator speed, energy savings of up to 50% could be achieved in trials while maintaining biogas production and process stability.

Further investigations showed that the biogas storage capacity of fermentation slurry has a measurable influence on the apparent biogas production: During periods when the agitators are turned off, biogas accumulates in the solid-liquid phase and can be released by agitation. However, this effect is too small, compared to the reactor volume and the gas storage capacity of membrane accumulators, to be used technically.

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

Bundesministerium für Ernährung und Landwirtschaft (BMEL)
Reference Number:
22402716

Partners:
Fraunhofer IKTS
TU Berlin
DBFZ
RTO

Duration:
May 2020 – Junie2023

View into a research fermenter (2021, University of Hohenheim).

PowerLand 4.2 – Smart and Innovative Land Power Systems

M. Eng. Celina Dittmer

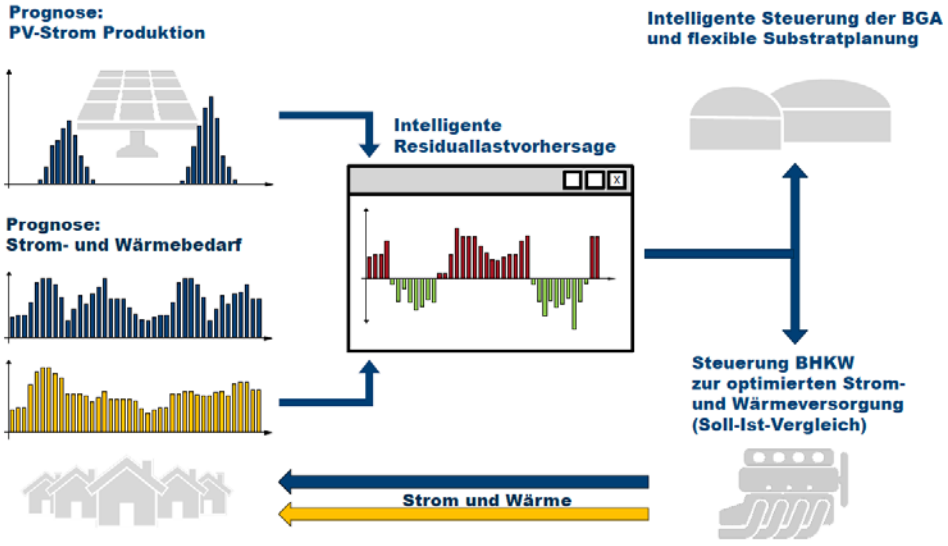
Dr. Johannes Krümpel

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 considered. 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.



Flowchart of the plant control system for demand-driven electricity and heat production

Funding:
Bundesministerium für Ernährung und Landwirtschaft
Fachagentur für Nachwachsende Rohstoffe e.V.

Partners:
Hochschule Reutlingen, Reutlinger Energiezentrum (REZ)
NOVATECH GmbH

Duration::
Oct. 2018 – Sep. 2021

Development of innovative and intelligent sensor systems to ensure biological process stability during load-flexible operation of biogas plants (i²-Sens)

M.Sc. Leoni Neubauer

Dipl.-Ing. Benjamin Ohnmacht

Dr. Johannes Krümpel

PD Dr. Andreas Lemmer

The load-flexible, demand-oriented operation of full-scale biogas plants is becoming increasingly important. After biogas plants have continuously produced biogas for many years, their future role in the regenerative-based energy supply will be to balance the fluctuating electricity production from wind energy and photovoltaics. This requires a change in the mode of operation to a strongly fluctuating plant feed, both daily and seasonally, in order to meet the fluctuating biogas demand.

This requires a reliable forecast of the biogas demand and a derived forecast of the biogas production. This work has already been implemented very successfully in a model predictive control in the predecessor project "PowerLand 4.2" around Celina Dittmer, Johannes Krümpel and Andreas Lemmer.

In a further step towards a holistic application of demand-oriented biogas production in full-scale plants, these models are to be extended to include process monitoring. This is necessary, for example, in order to react early to critical conditions in highly flexible feeding. Within the framework of i²-Sens complementary measuring techniques, consisting of photoacoustic-nondispersive infrared sensors and Raman spectroscopy, for temporally high-resoluting and highly accurate measurements of the biogas composition are to be used. Based on these data, conclusions on process stability and efficiency will be drawn and integrated into the existing models for flexible feeding.

At the beginning of the project, the requirements for the new measurement techniques and for the data acquisition at the research biogas plant at Unterer Lindenhof were made. In the following, a measuring device for biogas measurement directly in the digester will be developed and the new measurement techniques will be tested on a practical scale.

The project is coordinated by the state institute. In addition to the installation and validation of the gas measurement techniques, we investigate the relationships between biogas process and biogas composition in order to derive efficient feeding strategies for a stable and demand-oriented biogas production.

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

Bundesministerium für Ernährung und Landwirtschaft (BMEL)

Reference Number:
2220NR092A

Partners:
Union Instruments GmbH

Duration
Aug. 2021 – July 2024

The biogas composition will be measured directly in the digester in order to be able to react to process disturbances at an early stage (2018, University of Hohenheim

Numerical simulation of a novel biogas upgrading process for small volume flows for its technical and economic evaluation (BEREIT)

PD Dr. Andreas Lemmer

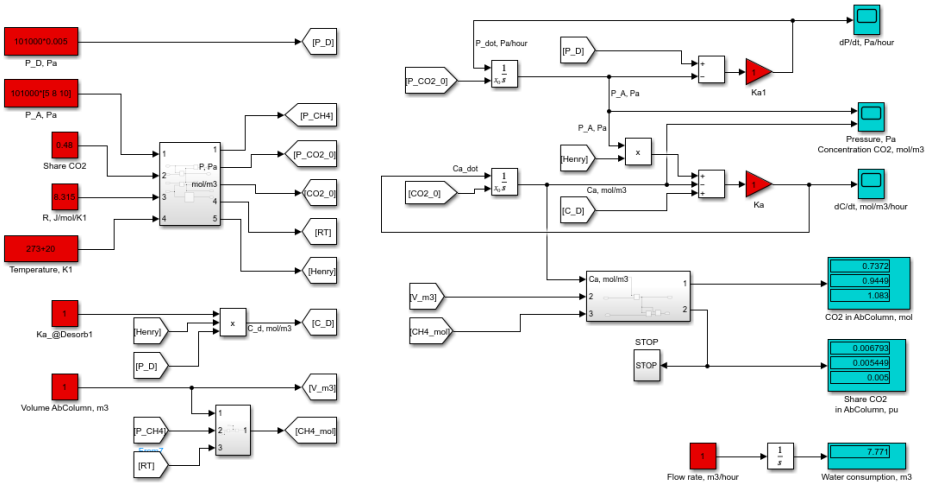
Dr.-Ing. Anastasia Oskina

M.Sc.. Nadiia Nikulina

In 2018, approximately 1,000 biogas plants in Baden-Württemberg covered 6.7% of gross electricity consumption. The majority of biogas plants utilize the produced biogas on site by means of direct electricity generation in the CHP (combined heat and power) units. In contrast, the option of biogas upgrading and feed-in is seldom used. According to FNR (2022), 222 biogas plants with a capacity of 141,120 m³/h fed biomethane into the natural gas grid throughout Germany in 2021. Due to the high investment costs to date, biogas upgrading has only been economically viable for very large plants with a raw gas volume flow of over 1000 m³/h. Biogas upgrading and further injection into the natural gas grid allows a versatile use of biomethane in the building sector as well as in the energy generation sector, industry and transport.

The objective of this feasibility study is the conceptual design and technical-economic evaluation of a compact, efficiency- and cost-optimized biogas upgrading plant. This upgrading plant is to be designed for a small volume flow of 175 m³/h, which corresponds to a capacity of approx. 350 kW of installed electrical power when utilized in a CHP unit. The process is based on a technically considerably simplified pressure water washing in sequential batch operation.

Based on the laws of thermodynamics and the designed operational setup, the physical processes within the absorption column were described mathematically using differential equations. Based on this mathematical model, the corresponding numerical simulation model was developed in MATLAB/Simulink. The model combines the pressure inside the column, temperature, CO_2 concentration and calculates the required flow rate of water passing through the column to achieve the desired methane concentration in the product gas. The overall evaluation demonstrates that the selected process approach is potentially technically and economically feasible.



Numerical Simulation developed in MATLAB/Simulink

Funding:
Ministerium für Ernährung, Ländlichen Raum und Verbraucherschutz Baden-Württemberg (MLR)

Duration:
Nov. 2020 – Juli 2021

Innovative Prozesskette zur ressourceneffizienten Erzeugung von Bio-LNG (Pro-BioLNG)

M.Sc. Elena Holl

M.Sc. Jörg Steinbrenner

PD Dr. Andreas Lemmer

The reduction of CO2-emissions in the industrial as well as private sector is indispensable for reaching the climate goals set by the german government. Particularly in the aviation sector, shipping and heavy transport, where proceeding electrification is difficult to intigrate, biological fuels are a competitive alternative to fossil fuels. In this case using Bio-CNG (compressed biomethane) or Bio-LNG (liquified biomethane) from renewable ressources and residues for powering the heavy transport and shipping sector as well as construction and agricultural machines is a promising concept.

The goal of the research project ProBioLNG is the development of an innovative and highly efficient process chain for the cost-efficient production of biomethane-based fuel whereby using application-oriented fundamental research. This biomethane-based fuels can thereafter be used as liquified Bio-LNG in the heavy transport, shipping, construction and agricultural sector. For this purpose individuals from science and economy incorporate their engagement to link proven and completely new technologies creating an innovative preocess chain.

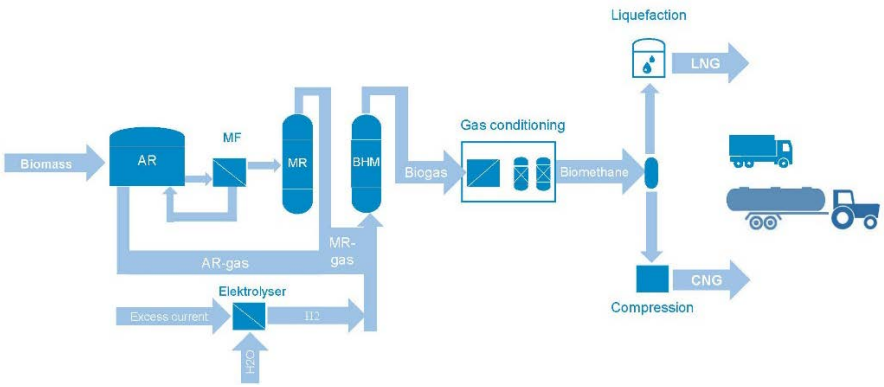
The whole research projection is managed by the State Institure of agricultural engineering and bioenergy. In ProBioLNG the institute is investigating the pressurized two-stage fermentation of biomass with a subsequent biological hydrogen methanation (Power-to-Gas) for biomethane and following fuel generation. Studies regarding the pressurized fermentation are conducted in the laboratory as well as pilot plant scale. Therefore a demonstration plant is developed and errected at ,,Unterer Lindenhof" in cooperation with project partners. Following the plant construction, experiments in the thoroughly linked operation are executed to illustrate the whole potential of the ProBioLNG process chain.

In the second year of the project, the detailed engineerig of the intended pilot plant as well as first construction work started. Moreover experiments regarding the biological hydrogen methanation were conducted in the laboratory, providing information about process conditions. Furthermore, a project homepage was launched to present news about the project to the public.

Funding:
Projektträger Jülich (PtJ)

Partners:
DVGW-Forschungsstelle am Engler-Bunte-Institut KIT Mobima
Class selbstfahrende Erntemaschinen GmbH
AirLiquide Forschung und Entwicklung GmbH

Duration:
Sep. 2019 – Aug. 2022



Innovative process chain for the production of Bio-CNG and Bio-LNG with two-stage anaerobic digestion composing of acidification reactor (AR), membrane filtration (MF), methane reactor (MR) followed by a biological hydrogen methanation (BHM) and subsequent gas treatment

Industrial research on the process chain of fuel production and operation of public transport buses with bio-LNG and bio-CNG from waste and residual materials (NeoBus - negative emission public transport)

M.Sc. Elena Holl

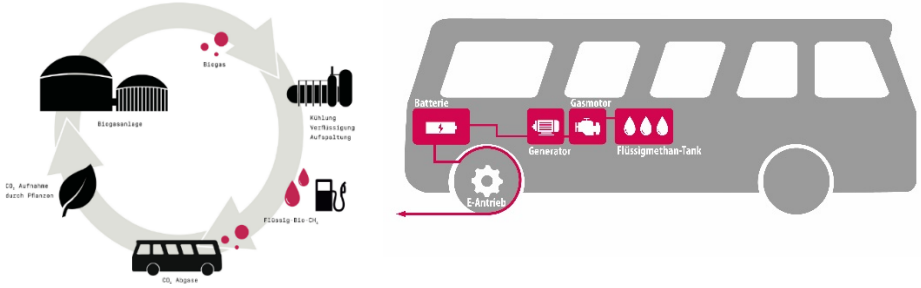
PD Dr. Andreas Lemmer

The reduction of CO2-emissions in the industrial as well as private sector is indispensable for reaching the climate goals set by the german government. Therefore, the EU has adopted the Clean Vehicle Directive (CVD), which is intended to lead to lower emissions, especially in cities. At present, however, bus operators consider neither electric drives nor hydrogen fuel cell hybrid technologies to be suitable for regional public transport from a technical and economic point of view. On the other hand, compressed biomethane (bio-CNG) or liquefied biomethane (bio-LNG) can both meet required standards and be produced locally in sufficient quantities.

Content of the project is the industrial research on the operation of buses with bio-LNG or bio-CNG produced on-farm with the overall goal of reducing CO2 emissions to less than 0 kg per kilometer. The entire process chain from on-farm production of bio-LNG and bio-CNG to tank logistics, adaptation of the buses' range and performance to the requirements of regional public transport, and the required tank and workshop technology will be evaluated comparatively. The drive concepts used are a bio-LNG hybrid concept (electric drive with recuperation and replenishment of the battery via gas engine) and a bus powered by bio-CNG with a gas Otto engine. In addition to the economic and technical aspects, the greenhouse gas balances of the two process chains bio-LNG and bio-CNG are to be investigated comparatively under practical conditions.

Based on the ongoing joint project ProBioLNG, the state institute is validating the on-farm production of methane-based fuels in the NeoBus project. For this purpose, the technical planning and acquisiton of a mobile LNG filling station for operation at the "Unterer Lindenhof" is carried out. This will be followed by the construction, installation and commissioning of the bio-LNG filling station at the pilot plant. Finally, data will be collected during the entire operation period to obtain a qualitative and quantitative statement about the functionality of the LNG production.

At the beginning of the project, the focus is on the completion of the pilot plant of the ProBioLNG joint project. In addition, the acquisition of an LNG refueling station is being pursued. Furthermore, initial discussions have been held with the subcontractor CM Fluids regarding a CO2 balancing as well as a possible certification of the produced fuels according to RED2 standards.



Sustainable cycle for bio-methane-based fuels and vehicle concept from CM Fluids

Funding:
Projektträger Jülich (PtJ)
Projektträger des Ministeriums für Ernährung, Ländlichen Raum und Verbraucherschutz Baden-Württemberg (VDI/VDE/IT)

Partners:
Lauer&Weiss GmbH
Bottenschein Reisen GmbH
Duelli Energie GbR
Omnibusverkehr Bühler GmbH & Co. KG

Duration:
Oct. 2021 – March 2023

BIOGAS PROGRESSIV – strategies for the optimization of agricultural biogas plants (ProBiogas)

Dr. Benedikt Hülsemann

Dr. Hans Oechsner

A high number of strategies for the optimization of the biogas production is allready developed and tested by universitys, state institutes and companies of the industry. However, a evaluation of this strategies for the implementation at agricultural biogas plants as well as an offer for the information of the operators are missing till now. The aim of the project "BIOGAs PROGRESSIV" is to fill this gap.

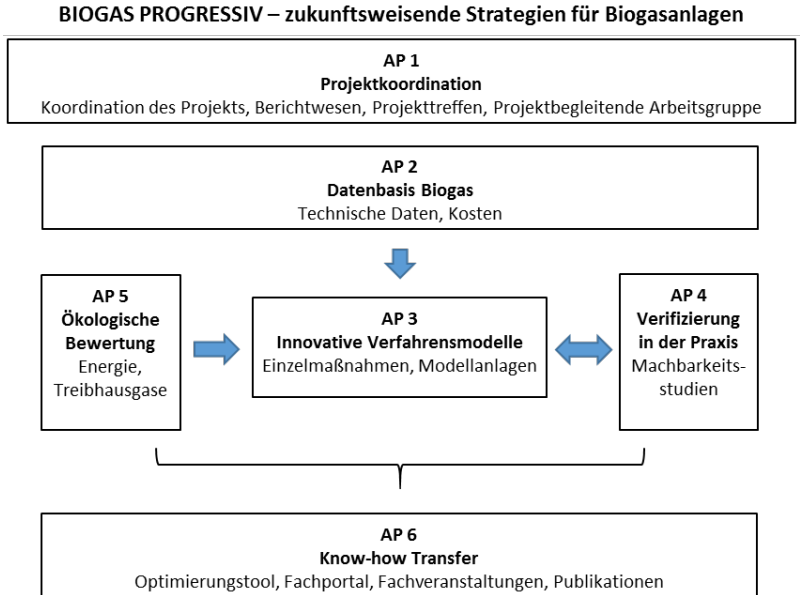
To reach this aim, a data collection to different innovative concepts is done. For that, several research institution and companies for the production and construction of biogas plant and components are contacted. The recorded data will be used for the development of strategies to optimize existing agricultural biogas plants. These strategie will be developed for eight biogas plants in the state Baden-Würtemberg and Bavaria. The developed strategie are evaluated technically, econimically and ecologically. Based on these results, a reccomendation for a optimization should be done for different kind of biogas plant.

At the end of the project, a large proven offer of information for biogas plant operator, agricultural consulter, engineering offices, municipalities, approval authorities, banks, investors and politic are availible. The know-how transfer will be done by a free online application , professional events and convention, by publication at the homepage of the KTBL and other publication (scientific paper or final report).

Funding:
Bundesministerium für Ernährung und Landwirtschaft
Fachagentur für Nachwachsende Rohstoffe e.V.

Partners:
Kuratorium für Technik und Bauwesen in der Landwirtschaft e. V. (KTBL), Darmstadt
Landwirtschaftskammer Niedersachsen, Fachbereich Energie, Bauen, Technik, Oldenburg

Duration:
Dec. 2017 – July 2021



Working packages in the project „BIOGAS PROGRESSIV – strategies for the optimization of agricultural biogas plants

Development of implementable strategies for the reduction or avoidance of climate-relevant emissions from the storage of farm manure with special consideration of the agricultural structure in Baden-Württemberg (MLR-Emissions)

M.Sc. Bastian Kolb

B.Sc. Teresa Knill

Dr. Hans Oechsner

The German government's Climate Protection Program 2030 sets the goal of greatly reducing methane emissions from farm manure storage. In addition to increasing the fermentation of farm manure in biogas plants with subsequent gas-tight storage of fermentation residues, the gas-tight storage of liquid manure is also mentioned for this purpose. However, if such storage tanks are not combined with a biogas plant, there are risks associated with them for the operator of such facilities. Even in unheated storage tanks, methane is produced which, together with air, can result in explosive mixtures.

On the other hand, however, technical possibilities exist to utilize the manure via biogas plants in order to largely avoid uncontrolled methane emissions and to reduce the associated CO2 emissions. In Baden-Württemberg, farm manure from cattle farming accounts for the largest share of the potential for farm manure fermentation, at around 75%. However, according to the state's own estimates, only about 25% of the manure produced is currently used for energy in biogas plants. There are currently just under 1,000 biogas plants in Baden-Württemberg. These are mainly located in regions with the highest density of livestock. Thus, in many cases it should be spatially possible to bring farm manure to existing biogas plants with manageable transport distances.

The aim of this study is to examine how an improved utilization of the accruing liquid manure and the (so far) unused solid manure via biogas technology is possible and which additional incentives are necessary. The survey is to be carried out exemplarily in two regions (Hohenlohe and Oberschwaben).

The following approaches are to be explored as examplary for the regions:

- Small biogas plants at single farms (less than 75 kW theoretical potential).
- Transport of fresh manure to existing biogas plants in the vicinity.
- Shared (community) biogas plants, possibly combined with shared storage.
- Use of separators for solid-liquid separation (increased transportability).

Funding:
Ministerium für Ländlichen Raum und Verbraucherschutz Baden-Württemberg

Partners:
Institut für Agrartechnik Universität Hohenheim

Landwirtschaftliches Zentrum für Rinderhaltung, Grünlandwirtschaft, Milchwirtschaft, Wild und Fischerei Baden-Württemberg (LAZBW)

Duration:
Apr. 2021 – Apr. 2022

Project partner with biogas plant over 75 kW power, which could be supplied with farm manure. Variants for the conversion to pure manure usage and combinations with substitutions of 20% solid manure or NaWaRo are calculated.

Development and construction of a novel, cost-effective, input-flexible and efficient solids biogas plant up to 75 kWel. (FeBio)

Dr. Benedikt Hülsemann

Dr. Hans Oechsner

In the future, mainly residual materials are to be used for biogas production. Especially for small, decentralized residual material quantities in rural areas, the use of small plants with a rated output of up to 75 kWel. is a technically reasonable solution. Currently, small wet fermentation plants are primarily designed for manure utilization and the use of solid residues is only possible to a limited extent. For residual materials with high dry matter contents, such as horse manure, complex pre-treatment is therefore necessary. The alternative of solid matter fermentation (TS >20%), which is more suitable from a technical point of view, currently has uneconomical power generation costs of >20 cents/kWhel for small plants.

A solid matter digester with investment costs below 8,000 €/kWel. is to be developed in order to enable electricity production costs of less than 15 cents/kWhel. for small plants. For this purpose, low construction costs, low transport and storage costs, a regional use of the residual materials as well as the realization in a kind of builder-owner model are planned.

With the construction and operation of a prototype under real operating conditions, project planning and operating experience will be gathered. During operation, optimizations based on operating experience with different substrates and operating conditions will be incorporated. The need for adaptation of existing legal regulations is determined along the entire project planning chain. If the economic and technical feasibility is proven, a plant is then brought to final market readiness by the participating SME.

The tasks of the state institute in the project are the preparation of a substrate management concept and the monitoring and optimization of the plant operation with regard to substrates and gas yields. The substrate sources have been developed. Currently, the granting of the building permit is to follow in order to be able to start the construction of the plant..

Funding:
Bundesministerium für Wirtschaft und Energie (BMWi)
Projektträger Jülich (PtJ),

Partners:
IZES gGmbH
Ökobit GmbH

Duration:
Jan. 2020 – Dec. 2023

Solids fermentation plant (Pertagnol, 2019)

DEMETHA – De-methanization of liquid manure: Intelligent energy supply in rural areas through flexible energy supply with liquid manure plants

M.Sc. Jörg Steinbrenner

M.Sc. Elena Holl

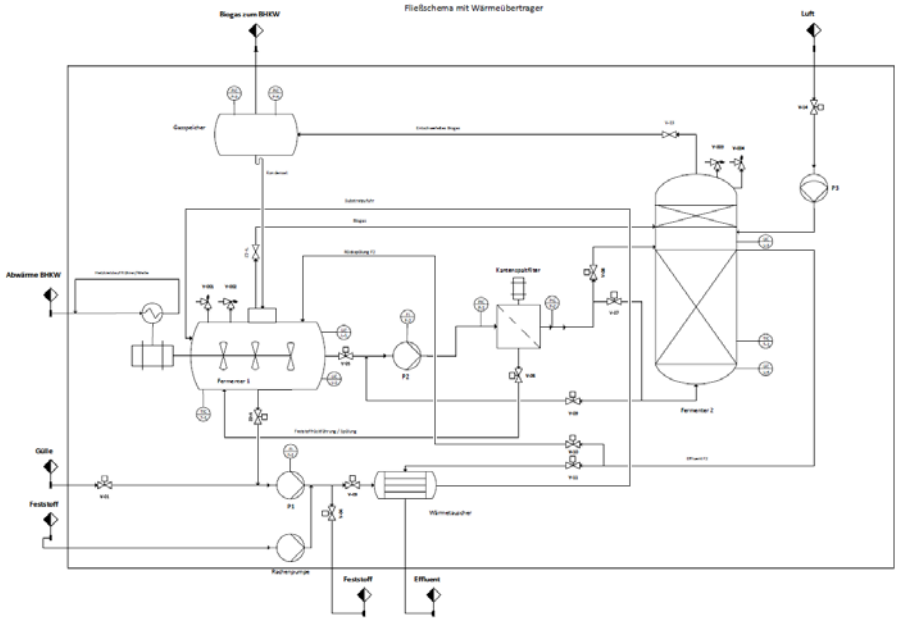
PD Dr. Andreas Lemmer

In Germany, agriculture is responsible for over 59% of methane and 95% of ammonia emissions (Umwelt Bundesamt, Umwelt und Landwirtschaft 2018). Among these, the most important sources of methane are emissions during the animal digestion process of ruminants and emissions from the storage of solid manure and slurry.

The objective of the Demetha project is to develop highly standardized manure based anaerobic digestion plants for farms with animal populations of approximately 150 livestock units (LSU) or more. These manure handling plants are based on the concept of the Hohenheim anaerobic two-stage manure digestion, consisting of a stirred tank reactor and a fixed bed reactor with recirculation of undegraded fiber between the two process stages. These standardized plants offer a very large transfer potential to a large number of farms, not only in Germany. The development of this standard plant could, on the one hand, make the raw material liquid manure available nationwide and, on the other hand, significantly reduce the greenhouse gas emissions associated with storage.

The entire research project is being coordinated by the State Institute. In which, the Landesanstalt is investigating the two-stage manure fermentation on a laboratory scale and, together with Hochland Natec GmbH, is responsible for the design and project planning of the possible pilot plant. The project is also being supported by Renergie e.V., which are determining the technical usable manure potential and conducting an ecological analysis of the process.

In the first year of the project, the mass balance was drawn up for the anaerobic two-stage manure digestion plant, the raw material potential was determined and a potential demonstration plant was designed.



Process flow diagram of the anaerobic two-stage manure digestion plant consisting of a continuous stirred tank reactor and an anaerobic filter with an in between filtration unit

Funding:
Bundesministerium für Ernährung und Landwirtschaft (BMEL)
Fachagentur Nachwachsende Rohstoffe e.V. (FNR)

Partners:
renergie Allgäu e.V.
Hochland Natec GmbH

Duration:
Sep. 2020 – Aug. 2021

Mechanical disintegration of lignocellulosic substrates by means of a ball mill for substrate treatment and flexibilization of the biogas production (FLEX – CRASH)

M.Sc. René Heller

Dr. Benedikt Hülsemann

Dr. Hans Oechsner

The use of lignocellulosic residues such as horse manure, landscape maintenance material or straw from agriculture represent a new utilization path for biogas production. Since these substrates usually have high dry matter and lignin contents, special preliminary crushing is required for utilization in the biogas plant. Without this pre-crushing, the fermentation substrates are not completely and slowly degraded. This is accompanied by low methane yields and a resulting uneconomical operation. Furthermore, without a pretreatment, process-related problems arise, such as increased floating layers and a higher stirring effort in the fermenter. Mechanical pretreatment by means of a ball mill can accelerate the kinetics of the degradation and gas formation process, as well as increase the resulting methane yield of unused residues. Additonally, the process reliability and economic efficiency are enhanced. Therefore, it contributs to a flexible and sustainable electricity production.

The aim of the project is to further develop the ball mill and to optimize its design and process technology so that lignin-containing substrates can be optimally processed for flexible biogas production. As a result, operational as well as economic advantages can be expected. This would make the use of by-products and residual materials from agriculture in biogas plants attractive, therefore, replacing a part of energy crops grown for the biogas production. This would represent an improvement in the carbon footprint of the entire process chain and contribute to the sustainability of biogas plants.

Currently, plans are underway to install the ball mill at the full-scale research biogas plant "Unterer Lindenhof“. The substrate pretreatment plant is scheduled to be comissioned and integrated into the biogas process chain in July 2021.

Subsequently, the effects of the treatment on the methane yield and the conversion kinetics with a special focus on the use of these substrates for a flexible biogas production, are investigated in the laboratory and at the full-scale biogas plant. The quality of substrate treatment will be evaluated using sieve analysis and particle surface determinations. The comparison of laboratory and practical results as well as an economic assessment of the different modes of operation and a direct comparison with other disintegration technologies are further objectives of the project

Funding:
Bundesministerium für Ernährung und Landwirtschaft (BMEL)
Fachagentur Nachwachsende Rohstoffe e.V. (FNR)

Partner:
Institut für Agrartechnik Universität Hohenheim
Biokraft Energietechnik GmbH
Bio-Energie Heuberg GmbH & Co. KG

Duration:
Okt. 2020 – Sep. 2023

Setup and integration of the ball mill prototype at the "Unterer Lindenhof" research biogas plant

Wastewater-free Environmental Campus Birkenfeld - new technologies in building refurbishment for a sustainable resource management (Re-Lab)

PD Dr. Andreas Lemmer

Dr. Simon Zielonka

On the basis of a concrete application object - an existing student dormitory at the Environmental Campus Birkenfeld (UCB) of Trier University - an innovative recycling concept for wastewater and organic residues is to be implemented in the building stock. The concept is based on the separate collection and utilization of wastewater and biomass potentials. For the subsequent separate collection of wastewater streams, a newly developed double inliner process is to be used for the first time, enabling the separation of fecal wastewater in existing buildings. Via a vacuum system, the fecal wastewater, together with accumulating biowaste, is fed to an anaerobic recycling process for the production of biogas, while the graywater is treated for various uses.

The objective of the work at the University of Hohenheim is to test the black water or the black water-biowaste mixture for anaerobic degradability for the purpose of biogas production. For this purpose, methane yield tests of the black water and the food waste on the one hand and continuous fermentation tests to determine the possible space load and retention time on the other hand were carried out. Conventional single-stage operation was compared with two-stage biogas plants. These investigations were flanked by analyses of the nutrient content of the substrate and the heavy metal content or drug residues of the fermentation residue.

The results of the project provide first, concrete indications for the operation of a practical plant at the Environmental Campus Birkenfeld, which is fed with black water and food residues. From the point of view of process biology, the substrate combination of food waste plus black water can be evaluated very positively. In the investigations carried out, no disturbances of the fermentation biology were observed in any process phase.

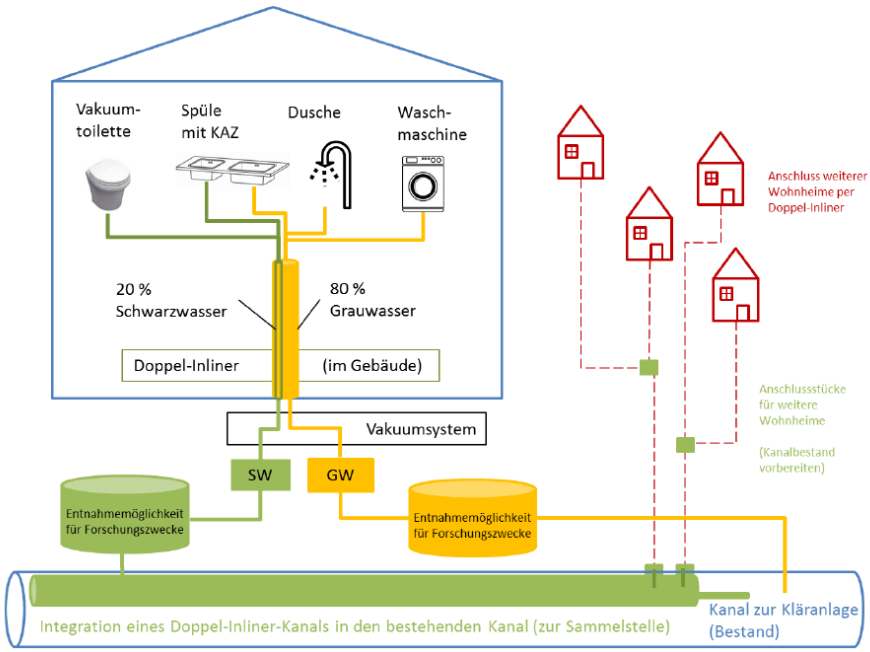


Illustration of the implemented construction measures at the Environmental Campus Birkenfeld for the separate collection of wastewater (black and gray water separation) (Source: Ifas, 2022).

Funding:
Forschungsinitiative Zukunft Bau

Bundesinstitut für Bau-, Stadt- und Raumforschung im Bundesamt für Bauwesen und Raumforschung

Partner:
Ifas, Hochschule Trier (Koordination)

Aqseptence Group GmbH,

Björnsen Beratende Ingenieure GmbH

Campus Company GmbH

TU Kaiserslautern, FG Ressourceneffiziente Abwasserbehandlung

Duration:
Okt. 2017 – Mai. 2021

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

M.Sc. Tahir Khan

Dr. Johannes Krümpel

PD Dr. Andreas Lemmer

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).

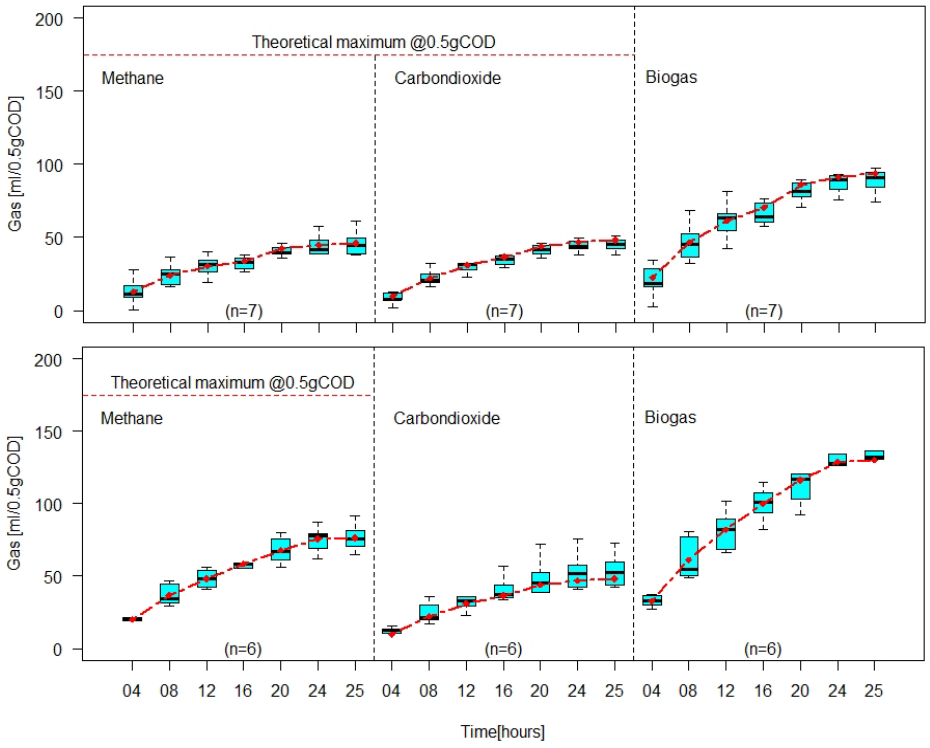
The goal of the project is to produce sustainable products with strong market potential, to guarantee a reliable and affordable supply of sustainably produced biomass, and to better link biomass producers with the processing industry. In order to avoid competition with the cultivation of food or feed 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.

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

Duration:
Juni 2017 – Nov. 2022



Cumulative gas production (methane, carbon dioxide, and biogas) in a continuous anaerobic process for Hydroxymethylfurfural (top) and Hydroxymethylfurfural process-wastewater (bottom)

Investigation of fermentability, methane potential and process stability in anaerobic fixed bed reactors in the utilization of dairy wastewater (KWA)

During the production of yoghurts in the dairy, there is a residue rich in organics, which largely consists of rinsing water, as well as whey and the washing water from the cup press. This residue can represent an interesting and cost-effective alternative to the usual substrates for biogas plants.

In order to assess the fermentability and the potential of the substrate, in the cooperation project with KWA Contracting AG, first tests are carried out with wastewater from industrial dairy operations in the Hohenheim biogas yield test. In addition, vegan yoghurts are examined for their potential.

Due to the low dry matter content, when fermenting in a stirred tank reactor, it should be noted that a large volume of water is passed through the biogas plant, which leads to large container volumes when the hydraulic retention time is high. Fixed-bed reactors with a high conversion rate and therefore a significantly lower hydraulic residence time can therefore represent a good alternative to this. In this research project, the wastewater from an industrial dairy company is to be examined in order to gain information on the design of a fixed-bed reactor on a practical scale. Particular focus is placed on the process stability and degree of degradation with different spatial loads. The investigations are accompanied by detailed chemical analyzes of the inflow and outflow.

Dr. Benedikt Hülsemann

M.Sc. Tahir Khan

Dr. Johannes Krümpel

Dr. Hans Oechsner

Substrate preparation: Filtration (left) and mixing (right) of the dairy wastewater

Partners & Funding:
KWA Contracting AG

Duration:
Okt. .2020 – Jan. 2021

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

M.Sc. Nadiia Nikulina

Dr. Hans Oechsner

Funding:
ERANETMED

Deutsches Zentrum für Luft- und Raumfahrt (DLR)

Partners:
Landesanstalt für Agrartechnik und Bioenergie - Universität Hohenheim (Koordination)

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

Duration:
Sep. 2017 – Feb. 2021

In rural areas of the MENA region (North Africa, Southern Europe), communities face several challenges: inadequate waste management infrastructure, limited access to low-cost energy, especially electricity, soils with poor fertility and water retention capacity.

The project aims to produce biogas from organic waste. This can be used for cooking or converted to electricity in larger plants. The digestate becomes high quality, pathogen-free compost.

The project has the following objectives:

- Laboratory tests for process optimization of dry fermentation.
- Methane yield potential determinations of the substrates from the MENA region and characterization of the digestate
- Design, installation and operation of a small demonstration plant of 5 m^3 with a planned electrical power of 500 W in Tunisia
- Preparation of life cycle assessment and techno-economic analyses
- Training of young scientists from the ERA and MENA region in Hohenheim several months stay of PhD students from Algeria, Turkey and Greece
- Information on biogas technology for researchers, farmers in the MENA region and the public via the project website, with work-shops and project conferences.

Laboratory tests were conducted on a semi-technical scale to optimize the dry fermentation process. Municipal organic waste (brown garbage can) was used as substrates. Optimal substrate mixture, process temperature, influence of the addition of liquid inoculum were investigated. Three different ratios of dry inoculum/substrate were investigated. During the tests, the process parameters volatile fatty acids, TS/oTS, pH and biogas quality and quantity were analyzed. The digestate was further investigated in the Hohenheim biogas yield test.

Batch-Reaktoren in the laboratory of the State Institue of Agricultural Engineering and Biogas (Nikulina, 2019)

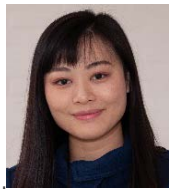
Adaptation of maize-based food-feed-energy systems to limited phosphate resources (AMAIZE – P)

In collaboration with the Agricultural University of China in Beijing, the University of Hohenheim has started the international research-training group (IRTG) with the title “Adaptation of maize-based food-feed-energy systems to limited phosphate resources”, short AMAIZE – P, in November 2018. The integrative project supported by the DFG incorporates the entire phosphate cycle in agriculture from plant nutrition to human and animal alimentation and nutrient recycling and economic evaluation with a total of 12 subtopics. The State Institute of Agricultural Engineering is involved in the research subject 3.3.

The focus of the first three years of the project was to evaluate the chemical behavior of phosphate in animal manure during anaerobic digestion. For this research sequential chemical extraction (fractionation) was used to evaluate the shift of phosphate between different salt fractions. The different fractions ranging from water extractable phosphate to calcium and magnesium as well as aluminum and iron bound phosphate show different short- and long-term plant availability. The knowledge of these shifts is essential for an optimized utilization of digestate as fertilizer and nutrient recovery from biogas digestate.

The results from the first stage of AMAIZE-P have shown that the frequently used adapted Hedley fractionation needed to be adapted for optimized phosphate analysis in digestate. Furthermore, experiments in batch and continuous biogas reactors have shown that phosphate is steadily mineralized during anaerobic digestion. This facilitates phosphate recovery as a pure phosphate salt. At the same time mid- to long-term plant availability of phosphate increases and short-term availability decreases. Meanwhile, experiments in continuous systems have shown that process parameters such as temperature and organic loading rate effect the phosphate composition significantly with a faster availability of phosphate at lower organic loading rate especially in calcium rich substrates

M.Sc. Konstantin Dinkler



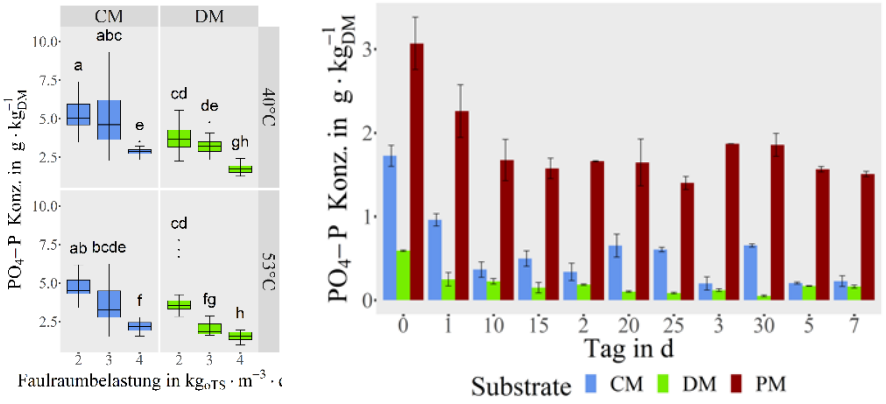
M. Eng. Bowen Li

M.Sc. Naga Sai Tejaswi Uppuluri

Prof. Dr. Joachim Müller

Dr. Hans Oechsner

Concentration of water-soluble phosphate



Changes of phosphate concentration depending on organic loading rate (OLR) and temperature in continuous systems (left) and on time in batch systems (right). CM: Chicken manure digestate; DM: Dairy manure digestate; PM: Pig manure digestate

Funding:
Deutsche Forschungsgesellschaft (DFG)

Partners:
China Agricultural University (CAU)
Dr. Jianbin Guo
M. Eng. Bowen Li

11 Institute der Universität Hohenheim

Duration 1st Projektphase:
Okt. 2020 – Okt. 2023

Combined Recovery of Nitrogen and Phosphorus from Agricultural Digestate within the Carbon Cycle (NitroPhos))

M.Sc. Konstantin Dinkler

Bowen Li M. Eng.

Dr.-Ing. Anastasia Oskina

PD Dr. Andreas Lemmer

Phosphorus, nitrogen, potassium and carbon are the most important nutrients for agriculture. In Germany, 82 million cubic meters of nutrient-rich digestate are produced annually. It consists of 0.2% phosphate and 0.25% nitrogen, which corresponds to 164,000 t P_2O_5 and 205,000 t N per year.

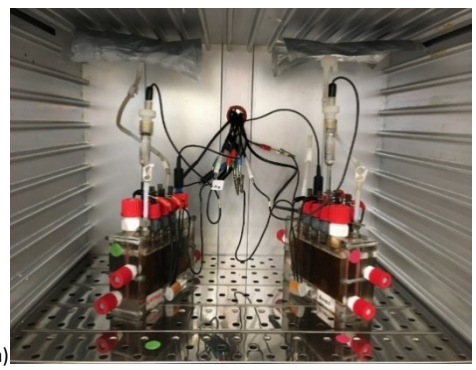
The objective of the project is to develop the best possible process combination for the separation of ammonium-nitrogen and phosphate from the fermentation residues of biogas plants in Baden-Württemberg. Ammonium nitrogen and phosphate are to be converted into highly concentrated, mineral fertilizer products with a high transportability. To reduce the necessity of digestate transportation, the goal of the study is a technology adaptation for on-farm application. The aim to is to extend the biogas plant functionality to nutrient management and high-quality fertilizer producing units.

The innovative process of the State Institute is based on microbially driven electrophoresis and aims to precipitate phosphate. By combining bio-electrochemical systems (BES) with the process of electrophoresis for phosphate separation, the energy requirement of nutrient extraction can be expected to be significantly reduced compared to conventional processes. However, according to the state-of-art a pH adjustment in the digestate is necessary to mobilize phosphate. Therefore, pH reduction with CO_2 and increase with NH_3 is tested in this study. CO_2 is readily available in form of biogas at biogas plants and NH_3 is produced as an intermediate product during nitrogen recovery.

Within the scope of the project, suitable processes for the separation of ammonium nitrogen and phosphate from fermentation residues are to be developed under the aspects of ecology and economy. Furthermore, their applicability in the field of agricultural biogas plants will be evaluated in order to examine to what extent the technologies have to be adapted and can be implemented.

Funding:
Projektträger des Ministeriums für Ernährung, Ländlichen Raum und Verbraucherschutz Baden-Württemberg (VDI/VDE/IT)

Duration:
Nov. 2021 – Jul. 2022

a)  b) 

View of BES reactors in the climate chamber (a) and view of crystal deposits on the surface of cathode after the experiment (b))

Fungi2Fabric – Fundamental research on the production of functional materials via ‘solid-state-fermentation’ using fungal mycelium and agricultural residues

M.Sc. Katharina A. Schoder

Dr. Johannes Krümpel

PD Dr. Andreas Lemmer

Concerning the currently prevailing waste problem, research into novel materials that can replace 'single-use products', such as packaging, is essential. One example is petroleum-based polystyrene, known under the trade name Styropor® which has many applications due to its many favourable material properties. However, this material must be replaced by environmentally friendly alternatives in the future.

One way of achieving this is with mycelium materials, which use the property of fungi to partially degrade substrate particles with their hyphal growth and function as a kind of natural adhesive. All lignocellulosic residual materials can be used as substrates. Composites with controllable properties are the results of the fungus, used substrate, and the selected production process. They offer a wide range of applications - similar to that of Styropor®. After their use, the materials can be degraded anaerobically due to their biogenic composition.

The 'Fungi2Fabric' project aims to advance basic research in this novel field of research and analyze the relationships between the substrates used and the resulting properties. Furthermore, new potential residual materials are to be identified. In addition, the further development of the production process, including the testing of the anaerobic degradability in biogas plants, is the focus of the work. As a result, process engineering and economic progress can be expected. All in all, CO_2 emissions can be saved, and local material cycles can be closed.

Experiments are currently being conducted to understand the factors influencing fungal species, substrate composition, pH and CO_2 availability on mycelial growth. The experiments will be completed in April 2022, and their results will be used to identify targeted residues from the agricultural sector suitable for composite production.

Further objectives of the project are to use various locally produced agricultural residues to produce test specimens and investigate and evaluate their material properties.

Left: Mycelium-based packaging materials made of hemp shives. Right: Produced samples for further materials testing.

Funding:
Nagelschneider-Stiftung – Erforschung nachhaltiger Energien

Partners:
Institut für Agrartechnik Universität Hohenheim

Duration:
Januar 2021 – Mai 2024

Evaluation of innovative processes for the production of plant fibers in regional added value to optimize the biogas process chain

Dr. Benedikt Hülsemann

B.Sc. Philipp Lang

Dr. Hans Oechsner

The biogas industry is currently at a peak, due to the expiry of the first payment period of the EEG for some biogas plants. Because of this, the generation of additional sales markets is a key issue in order to ensure the continued existence of biogas plants in Germany. Furthermore, using bioeconomy approaches, the added value of agricultural products can be significantly increased, which in turn contributes to climate protection.

As part of the project, the fiber production with simultaneous energetic utilization of agriculturally used plants and residues is to be investigated. As part of the concept, it is planned to separate the fibers as solid and use them for paper production, while the liquid is to be used for energy production in a biogas plant.

As part of the project, a screening of different agriculturally used plants and residues is to be carried out and on the basis of this the potential of the plants for fiber production is to be examined. As plants, in addition to Silphie, the focus is also on hemp, hops, nettles and miscanthus. Apple pomace, among other things, is examined as a residue.

The processing of the fibers of the selected plants and residues are then carried out using different methods. In practice, this should be done using steam explosions, cross-flow clamps and extruders, as well as in the laboratory using t.e. steam explosions, ball mills and Thermomix. After the preparation has been completed, the required two phases are generated in the laboratory by means of solid / liquid separation.

The technical, ecological and economic evaluation of the overall process is carried out with the help of mass and energy balances, biogas yield tests and various methods for determining the fiber quality (e.g. fiber length and water absorption capacity).

Funding:
Ministerium für Ländlichen Raum und Verbraucherschutz (MLR) Baden-Württemberg

Partners:
Hochschule für Medien Stuttgart
Hahnennest GmbH & Co. KG

Duration:
Dez. 2020 – Mai 2021

Laboratory scale steam explosion

Process technical investigation of fiber production from Silphium perfoliatum for paper production and energetically usage of the pulp fraction

The Silphium perfoliatum is an energy crop and an ecollogically alternative of maize for feeding biogas plants. The Silphium is planted and sold as well as used as substrate for biogas plant by “Hahnennest” in Ostrach since some years. However, Silphium contains out of fibre like other substrate, which cannot be degradable in an anaerobic process. That’s why it is sensefull to separate the fibre in a pretreatment and use it as educt for the paper production for producing cardboard packing. For the seperation of the fibre, a steam explosion, an entstipper and some additional seperator was build. In this process the fibre can be separated and used for the paper production during other parts of the plant will be the substrate of a biogas plant.

The aim of the project is the optimization of the pretreatment process as well as the investigation of the best harvesting time. For that, the methane potential and the particle size of the output of the pretreatment process by using input of different harvesting time, will be investigated. Based on this data, a mass and energy balance as well as a economic evaluation will be done.

The Silphium perfoliatum was harvested and ensiled three times every three weeks between september and october 2020. The fibre content is fluctuated between the three harvesting time. A higher fibre content has a positiv effect on the amount of the production of fibre, but a negative effect on the input substrate of a biogas process. The economic optimum between both should be find.

The new process chain could follow in a bioeconomic concept, which produce beside energy also other paper for getting higher valuarbility products in a close circle process. This would folow in a more sustainable and economically higher process.

Dr. Benedikt Hülsemann

M.Sc. Marian Baumgart

B.Sc. Marzieh Eslami

Dr. Hans Oechsner

Silphium (van der Sanden, 2020)

Funding:
Ministerium für Ländlichen Raum und Verbraucherschutz (MLR) Baden-Württemberg

Partners:
Hahnennest GmbH & Co. KG

Duration:
Juli. 2020 – Mai 2021

Optimization of the ensilage of the Cup Plant Silphium Perfoliatum to improve subsequent fiber separation and paper production (SILPHIE – SIL)

M.Sc. Marian Baumgart

Dr. Benedikt Hülsemann

Dr. Hans Oechsner

To increase value creation in rural areas, new or optimized utilization paths in agriculture are being sought as part of Baden-Württemberg's bioeconomy initiative. The use of energy crops, such as the cup-plant Silphie, is for the production of energy is already established in Baden-Württemberg. The cultivation of the growing cup-plant is particularly interesting, since the perennial plant promises significant ecological advantages over corn. However, due to its high fiber content and the resulting low spec. methane yield (approx. 250 L CH4/kg oTS), the fermentation of this is not economically competitive compared to corn (approx. 340 L CH4/kg oTS (KTBL,2013)). One reason is that the fibers can not be degraded to methane in the biogas plant. With the help of thermal haydrolysis, a physical-thermal pretreatment, these natural fibers can be separated and used as a high-quality product for paper production. The resulting liquid (pulp) with the other cell ingredients, is also highly fermentable.

It has been shown that the ensiling of cup-plants as chopping material is not without problems. The content of lactic acid in the silage is very low compared to other energy crops, and butyric acid is formed as a result of faulty fermentation, causing both the silage and the fiber obtained from it to have an unpleasant odor, which reduces the marketability of the fiber.

In the Silphie-Sil project, the harvesting and ensiling process of Silphium Perfoliatum will be optimized in the laboratory with the addition of bacterial cultures and other additives to obtain a rapid pH drop, low ensiling losses, and a low-odor fiber product. The overall objective is to increase the formation of lactic acid in the silage so that the formation of butyric acid can be reduced, thus improving the storage stability of the silage, reducing odor emissions and increasing the yield of biogas from the remaining pulp. For this purpose, three harvest dates of the cup-plant and the composition of the fermentation acids during the entire ensiling phase are investigated. The fibers are then separated through the thermal pressure haydrolysis process and examined for use in the possible production of paper (fiber quality, tensile strength, odor). The pulp is analyzed for methane potential and toxic substances (phenols, furfurals).

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

Bundesministerium für Ernährung und Landwirtschaft

Partners:
Institut für Agrartechnik Universität Hohenheim

Duration:
Nov. 2021 – Jul. 2022

First harvest date of the cup-plant (left) ensiled with addition of ensiling aid (middle) and opening of the waking glasses after 90 days (right).

Energy and Substrate Coupling of Biogas Plant and Biorefinery (BioKop)

Dr.-Ing. Anastasia Oskina

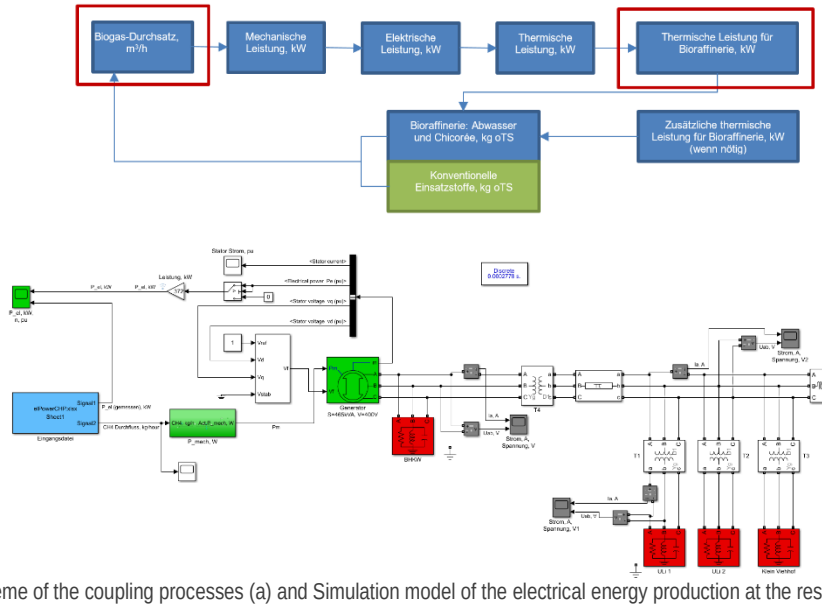
PD Dr. Andreas Lemmer

In terms of a sustainable bioeconomy, it is necessary to operate decentralized biorefineries. The concept of the BioKop project is based on the coupling of biorefinery with combined heat and power unit of a biogas plant. In this project an energetic and a full-scale substrate coupling shall be worked out. The project will be developed and implemented firstly at the experimental station "Unterer Lindenhof" and then it should be generalized for any biogas plant.

Through the coupling with the biogas plant, the recycling of nutrients is provided, the project thus also follows the goals of sustainability and closed circular economy. The decentralized concept allows the lean usage of on-site produced biomass. A special aspect here is the biogas plant, which becomes a part of the decentralized value chain. In this project, the balance between electrical and thermal energy is re-evaluated and optimized with consideration of the substrate flow as well as the heat usage by the biorefinery.

The MATLAB simulation models of electrical and thermal energy production were developed. On the basis of these simulation models, the energy usage was analysed, and different scenarios of heat utilisation were considered. In order to cover heat demand of the biorefinery, the installation of an additional heat exchanger for waste gases was considered, using thermal oil as a cooling fluid. The technical parameters of the new waste gas heat exchanger were calculated and an updated PI-Diagram was elaborated. Additionally, the mathematical model for estimation of potential biogas yield in the case of substrate coupling was developed.

The MATLAB simulation models of the biogas plant are to be coupled with the ASPEN Plus simulation model of the biorefinery to enable the substrate coupling of both functional parts.



Scheme of the coupling processes (a) and Simulation model of the electrical energy production at the research station Unterer Lindenhof (b

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

Partners:
Fg. Konversionstechnologien nachwachsender Rohstoffe (440f), Universität Hohenheim

Duration:
Dez. 2020 – Dez. 2021

Hohenheim Biogas Forum at the Biogas Info Days in Ulm, 2021

Dr. Padma Priya Ravi

M.Sc. Nadiia Nikulina

PD Dr. Andreas Lemmer

The annual trade fair "Biogas Info Days " of Renergie Allgäu e.V. is the largest annual trade fair in southern Germany and one of the top trade fairs in the biogas industry nationwide. In addition to the classic industrial fair, the three lecture forums (science, practice and innovation) are also a fixed and popular component of the Biogas Info Days. These forums are free for the fair visitors as well as for the exhibitors. Thus, the audience of the forums is composed of biogas plant operators, representatives of companies, authorities, associations, societies and science. This constellation makes the Biogas Info Days ideally suited for the transfer of knowledge into agricultural practice.

The Hohenheim Biogas Forum at the Biogas Info Days 2021 is a two-day, single-session science forum in hybrid format with a total of 12 presentations. It offers trade fair visitors independent information on current research in the field of biogas. The forum was organized, moderated and thematically designed by the staff of the State Institute.

The project served the transfer of knowledge from research to agricultural practice with a focus on the topic of biogas. However, due to the current situation in the biogas industry, topics that have so far been treated as side issues, such as biorefineries, are becoming increasingly relevant. As current thematic focal points for the Hohenheim Biogas Forum, the following blocks of topics have been identified and addressed in each case via various presentations:

- Manure fermentation & sustainability of biogas plants
- Material flows & fertilizer regulations
- Alternative substrates for biogas plants
- Biorefinery concepts for the production of composite fibers

In addition to the lectures, a scientific poster exhibition in the foyer of the fair was also equipped by the University Hohenheim. Here, 15 posters of scientific projects on the topic of biogas were presented.

Funding:
Bundesministerium für Ernährung und Landwirtschaft (BMEL) Fachagentur Nachwachsende Rohstoffe e.V. (FNR)

Duration:
Mai 2021 – Okt. 2021

Research biogas plant "Unterer Lindenhof

PD Dr. Andreas Lemmer

Dipl.-Ing. Benjamin Ohnmacht

The biogas plant "Unterer Lindenhof" is one of the most successful large-scale research facilities at the University Hohenheim, which makes it possible to link practical, application-oriented research projects with highly complex basic research in an exemplary manner. The main topics are the system integration of bioenergy, the use and processing of organic residues as well as new process approaches for nutrient management on farms. Both the integration of biogas technology into future energy systems and the process engineering research projects require a "digitalization of biogas production". This requires a database-supported data management with an online acquisition of the process data of the plant and the integrated systems of the entire site "Lindenhöfe". The number of research projects conducted simultaneously at the research biogas plant again reached an all-time high in 2021:

- OptiFlex: Optimization of biogas plant operation and design for demand-driven biogas production.

- PowerLand 4.2: Fully automated system integration of bioenergy

- BioSaiFle: Utilization of FFH mowed material in biogas plants

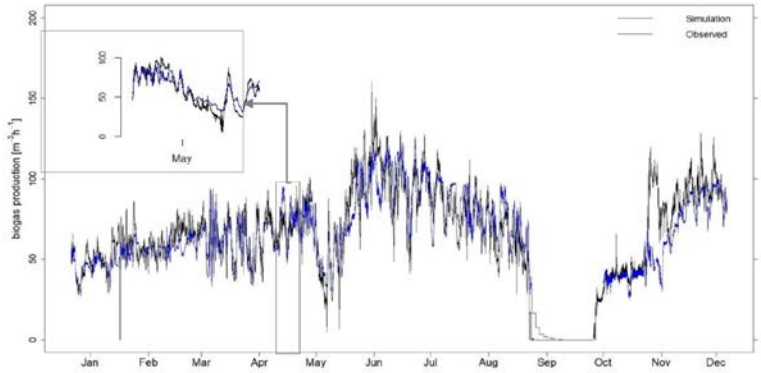
- Flex-Crash: Integration of a ball mill for the utilization of fiber-rich substrates

- Sens-O-Mix: Automation of agitation systems in load cycling operation of bio¬gas plants.

- Pro-BioLNG: Decentralized bio-LNG production as "negative-emission" fuel

- i²-Sens: Development of innovative and intelligent sensors to ensure process stability during load-flexible operation of biogas plants.

In addition to research, the State Institute is responsible for the operational management of the plant on behalf of the Rectorate, organizes its permanent technical updating and coordinates the research projects. A successful operation of this complex research equipment is only possible due to the great personal commitment of the staff of the Experimental Station Agricultural Sciences in the daily supervision of the plant as well as of Mr. Ohnmacht on the part of the State Institute. We would like to express our sincere thanks to all colleagues.



Simulated data of biogas production (blue) based on feeding and realized gas production (black) at the research biogas plant

Co-organized Conferences

ALB Fachtagung - „Schweinehaltung - Praktische Umsetzung zukünftiger rechtlicher Vorgaben“
11. März 2021, online Fachtagung, veranstaltet zusammen mit der Landesanstalt

Hohenheimer Biogasforum auf den Biogas-Infotagen
07.-08. Juli 2021, Messe Ulm, Ulm, veranstaltet zusammen mit dem Renergie Allgäu e.V.

Progress in Biogas V
22. -24. September 2021, Internationale online -Konferenz, veranstaltet zusammen mit dem IBBK

International Biogas & AD Training Course
19. Oktober -04. November 2021, Online-Kurs, veranstaltet zusammen mit dem IBBK

ALB Fachgespräch - „Milchziegenhaltung – Käseproduktion, Direktvermarktung“
18. November 2021, Sulzburghof, Unterlenningen, veranstaltet zusammen mit der Landesanstalt

University examinations 2021

Bachelor and Master theses

Sina Vervin
Planung einer verfahrenstechnischen Anlage zur biologismachen Wasserstoff-Methanisierung im Pilotmaßstab.

Marzieh Eslami
Process Engineering Studies on Biogas- and Fiber Production from Silphium perfoliatum L.

Marian Baumgart
Verfahrenstechnische und ökonomische Beurteilung des Faseraufschluss der durchwachsenen Silphie mit dem Verfahren der Thermodruckhydrolyse und anschließender Faserseparation

Christian Bidlingmaier
Wirtschaftlichkeit zukunftsfähiger Geschäftsmodelle für Biogasanlagen nach dem ersten EEG-Vergütungszeitraum

Teresa Knill
Wirtschaftlichkeit verschiedener Strategien für den Weiterbetrieb von Biogasanlagen nach der Förderperiode eins am Beispiel zweier Biogasanlagen in der Region Westallgäu- Oberschwaben.

International Exchange

International Guest Scientists to the State Institute

Giovanni Ferrari
Doktorand der Universität Padua. Life Cycle Assessment of ProBioLNG process chain

Publications 2021

Peer-reviewed

Cao, Z., Hülsemann, B., Wüst, D., Oechsner, H., Lautenbach, A., Kruse, A.
Effect of residence time during hydrothermal carbonization of biogas digestate on the combustion characteristics of hydrochar and the biogas production of process water. (2021) Bio. Techn. 333 (2021) 125110. DOI: 10.1016/j.biortech.2021.125110

Dinkler, K., Li, B., Guo, J., Hülsemann, B., Becker, G. C., Müller, J., Oechsner, H.
Adapted Hedley fractionation for the analysis of inorganic phosphate in biogas digestate. (2021) Bio. Techn. 333 (2021) 125038. DOI: 10.1016/j.biortech.2021.125038

Dittmer, C.; Krümpel, J; Lemmer, A.
Modeling and Simulation of Biogas Production in Full Scale with Time Series Analysis. In: Microorganisms 9 (2). DOI: 10.3390/microorganisms9020324.

Dittmer, C., Krümpel, J., Lemmer, A.
Power demand forecasting for demand-driven energy production with biogas plants
(2021) Renewable Energy, 163, pp. 1871-1877.

Hagemann, M.H., Born, U., Sprich, E., Seigner, L., Oechsner, H., Hülsemann, B., Steinbrenner, J., Wünsche, J.N., Lehmaier, E.
Degradation of hop latent viroid during anaerobic digestion of infected hop harvest residues. (2021) European Journal of Plant Pathology, 161, pp. 579-591. DOI: 10.1007/sl0658-02 l-02344-2

Hassa, J., Klang, J., Benndorf, D., Pohl, M., Hülsemann, B., Mächtig, T., Effenberger, M., Pühler, A., Schlüter, A., Theuerl, S.
Indicative Marker Microbiome Structures Deduced from the Taxonomic Inventory of 67 Full-Scale Anaerobic Digesters of 49 Agricultural Biogas Plants. (2021) Microorganisms 2021, 9(7), 1457. DOI: 10.3390/microorganisms9071457

Hülsemann, B., Mächtig, T., Pohl, M., Liebetrau, J., Müller, J., Hartung, E., Oechsner, H.
Comparison of Biological Efficiency Assessment Methods and Their Application to Full-Scale Biogas Plants. (2021) Energies 2021, 14, 2381. DOI: 10.3390/en14092381

Illi, L., Lecker, B., Lemmer, A., Müller, J., Oechsner, H.
Biological methanation of injected hydrogen in a two-stage anaerobic digestion process, (2021) Bioresource Technology, 333, art. no. 125126

Khan, M.T., Krümpel, J., Wüst, D., Lemmer, A.
Anaerobic degradation of individual components from 5-hydroxymethylfurfural process-wastewater in continuously operated fixed bed reactors, (2021) Processes, 9 (4), art. no. 677

Kumar Khanal, S., Lü, F., Wong, J.W.C., Wu, D., Oechsner, H.
Anaerobic digestion beyond biogas (2021) Bioresource Technology, 337, art. no. 125378

Nikulina, N., Uslu, S., Lemmer, A., Azbar, N., Oechsner, H.
Optimal conditions for high solid co-digestion of organic fraction of municipal solid wastes in a leach-bed reactor, (2021) Bioresource Technology, 331, art. no. 125023

Ohnmacht, B.; Lemmer, A.; Oechsner, H.; Kress, P.
Demand-oriented biogas production and biogas storage in digestate by flexibly feeding a full-scale biogas plant," Bioresour. Technol., vol. 332, no. April, p. 125099, 2021.

Sailer, G., Silberhorn, M., Eichermüller, J., Poetsch, J., Pelz, S., Oechsner, H., Müller, J.
Influence of Digester Temperature on Methane Yield of Organic Fraction of Municipal Solid Waste (OFMSW). Appl. Sci. 2021, 11, 2907. DOI: 10.3390/app11072907

Sailer, G., Knappe, V., Poetsch, J., Paczkowski, S., Pelz, S., Oechsner, H., Bosilj, M., Ouardi, S., Müller, J.
Upgrading the Organic Fraction of Municipal Solid Waste by Low Temperature Hydrothermal Processes. Energies 2021, 14, 3041. DOI: 10.3390/en14113041

Sailer, G., Eichermüller, J., Poetsch, J., Paczkowski, S., Pelz, S., Oechsner, H., Müller, J
Characterization of the separately collected organic fraction of municipal solid waste (OFMSW) from rural and urban districts for a one-year period in Germany. Waste Management 2021, 131, 471-482. DOI: 10.1016/j.wasman.2021.07.004

Sailer, G., Eichermüller, J., Poetsch, J., Paczkowski, S., Pelz, S., Oechsner, H., Müller, J.
Dataset for a full-year time series characterization of separately collected organic fraction of municipal solid waste from rural and urban regions in Germany. Data in Brief 2021, 39, 107543. DOI: 10.1016/j.dib.2021.107543

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, (2021) Biomass Conversion and Biorefinery, 11 (5), pp. 1453-1463.

Winquist, E., Van Galen, M., Zielonka, S., Rikkonen, P., Oudendag, D., Zhou, L., Greijdanus, A.
Expert views on the future development of biogas business branch in germany, the netherlands, and finland until 2030, (2021) Sustainability (Switzerland), 13 (3), art. no. 1148, pp. 1-20.

Zhou, L., Hülsemann, B., Cui, Z., Merkle, W., Sponagel, C., Zhou, Y., Guo, J., Dong, R., Müller, J.
Operating Performance of Full-Scale Agricultural Biogas Plants in Germany and China: Results of a Year-Round Monitoring Program. (2021) Appl. Sci. 2021, 11, 1271. DOI: 10.3390/app11031271

Conference proceeding posts

Effenberger, M, Eckel H., Lemmer A., Loewen, A., Paterson, M., Strobl, M.
Aspekte eines nachhaltigen Betriebs von Biogasanlagen. In: KTBL (2021): Biogas in der Landwirtschaft - Stand und Perspektiven. 7. FNR/KTBL-Kongress, Onlinetagung 29.-30.09.2021, Darmstadt, Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V., S., KTBL-Schrift 524, 132 – 140

Hagemann, M.H., Born, U., Sprich, E., Seigner, L., Oechsner, H., Hülsemann, B., Steinbrenner, J., Wünsche, J.N., Lehmaier, E.
Fate of the Hop latent viroid during ensiling of hop harvest residues. (2021) Acta Hortic. 1328. ISHS 2021. Proc. V. International Humulus Symposium; DOI 10.17660/ActaHortic.2021.1328.9

Hülsemann, B., Oechsner, H.
Efficiency analysis of biological systems of biogas plants: definition and accuracy. Progress in Biogas, 22-24.9.2021

Hülsemann, B., Oechsner, H.
Future concepts for biogas plants in Germany. Progress in Biogas, 22.-23.9.2021

Lemmer, A., Holl, E., Bär, K., Steinbrenner, J.
Dezentrale Erzeugung von LNG in einer neuartigen Prozesskette – Möglichkeiten und Grenzen. In: KTBL (2021): Biogas in der Landwirtschaft - Stand und Perspektiven. 7. FNR/KTBL-Kongress, Onlinetagung 29.-30.09.2021, Darmstadt, Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V., S. 55 – 65

Oechsner, H., L Zhou, R. Gerhards:
Inactivation of different weed seeds in the biogas process at different fermentation temperatures and retention times. International conference on biotechnology for sustainable agriculture, environment and health (BSAEH-2021), Jaipur, Indien, 4. – 8. April 2021, Tagungsband

Ohnmacht, B.; Lemmer, A.; Oechsner, H. und Kress, P.:
Optimierung des Betriebs und Designs von Rührwerken zur Senkung des Eigenstromverbrauchs von Biogasanlagen“, 7. FNR/KTBL-KONGRESS - Biogas in der Landwirtschaft – KTBL-Schrift 524, S. 114-121

Rubner, I., Baur, L., Grau, B., Steinbrenner, J., Hülsemann, B., Lemmer, A.
Curricular innovation research in the field of renewable energy using the example of anaerobic digestion and methane production. (2021) 9th International Conference on Sustainability, Technology and Education

Presentations

Brandhorst, C., Lemmer, A.
Methanerträge von FFH-Mähwiesen im Vegetationsverlauf. Biogas Infotage 2021, Renergie Allgäu e.V., Ulm, Hybrid, 07.-08.07.2021

Brandhorst, C., Lemmer, A.
Naturalistic management of lowland ha meadows for biogas production. Methane yields determination over the vegetation period. International online conference "Progress in Biogas V", 22-24.09.2021

Dinkler, K.
Phosphatgewinnung aus Biogas-Gärprodukten, 15. Biogastag Baden-Württemberg, 04.03.2021 Online, 22-24.09.2021

Dinkler, K.
Phosphate Analysis for an Optimized Recovery, Progress in Biogas V – International online conference, 22-24.09.2021, Online

Dinkler, K.
20. Süddeutsche Biogas Fachtagung, Aufbereitung von Gärresten Stand der Technik und Perspektiven, Online, 17.11.2021
Heller, R.
Pre-treatment of lignocellulosic residues by means of a ball mill, Progress in Biogas V – International online conference, 22-24.09.2021

Holl, E., Steinbrenner, J., Lemmer, A.
Development of an innovative process chain generating resource efficient biofuel based on methane. Workshop Biological Carbon Capture and utilization (BCCU), Online, 25.05.2021

Holl, E., Steinbrenner, J., Lemmer, A.
Development of an innovative process chain generating resource efficient biofuel based on methane. Progress in Biogas V, Online, 23.09.2021

Hülsemann, B., Oechsner H.
Effizienzbewertung des biologischen Prozesses – Vorstellung der Methoden und Darstellung der Kernergebnisse. Seminar Biogas-Messprogramm III, Online, 27.1.2021

Hülsemann, B., Oechsner H.
Biogas-Messprogramm III – Ist-Stand des Biogasanlagenbestands. 15.Biogastag Baden-Württemberg - WebSeminar, 4.3.2021

Hülsemann, B., Föllmer, M., Oechsner, H., Franz, M.
Bewertung von innovativen Verfahren zur Gewinnung von Pflanzenfasern in regionaler Wertschöpfung zur Optimierung der Biogas-Verfahrenskette. Statusseminar MLR Bioökonomie, Online, 23.6.2021

Hülsemann, B., Oechsner, H.
Efficiency analysis of biological systems of biogas plants: definition and accuracy. Progress in Biogas, Online, 22-24.9.2021
Hülsemann, B., Oechsner, H.
Future concepts for biogas plants in Germany. Progress in Biogas, Online, 22.-24-.9.2021

Hülsemann, B., Baumgart, M., Oechsner, H.
Faser- und Biogasproduktion aus Durchwachsener Silphie -Prozesstechnische Bewertung. Bayreuther Silphie-Symposium, Online, 28.10.2021

Hülsemann, B.
Erkenntnisse aus dem Biogas-Messprogramm III und mögliche Entwicklungsoptionen für die Biogasanlagen nach dem Ablauf der EEG Förderung, Biogas aktuell, Online, 7.12.2021

Krümpel, J.
Automated feeding management of biogas plants for optimal system integration of bioenergy, Progress in Biogas V, Online 2021

Lemmer, A., Morozova, I. Nikulina N., Krümpel, J.
Einfluss von Stickstoff auf die Prozessstabilität. (2021) 15. Biogastag Baden-Württemberg – WebSeminar, 04. März 2021

Lemmer, A., Krümpel, J.
An introduction to Digester Biology. (2021) IBBK Biogas Online Training, Module 5 – Theory & Practice of Digester Biology in AD, online workshop, 03-30-2021

Lemmer, A., Krümpel, J.
An introduction to Digester Biology. (2021) IBBK Biogas Online Training, Module 5 – Theory & Practice of Digester Biology in AD, online workshop,10-26-2021

Lemmer, A., Krümpel, J
Importance of process stability for sustainable biogas production. (2021) Progress in Biogas V, online conference, 22.-24.09.2021

Lemmer, A., Holl, E., Steinbrenner, J.
Bio-CNG und Bio-LNG: Verfügbare zero-emission Kraftstoffe für den Schwerlastverkehr und den ÖPNV. (2021) 06. Bioökonomietag Baden-Württemberg, 18. November 2021

Lemmer, A., Holl, E., Steinbrenner, J.
Dezentrale Erzeugung von LNG in einer neuartigen Prozesskette, Möglichkeiten und Grenzen. (2021) FNR-KTBL Kongress „Biogas in der Landwirtschaft – Stand und Perspektiven “ 29. Oktober 2021

Oechsner, H.:
Effizienz von Biogasanlagen. In: Fortbildung Basisqualifikation „Grundlagen der Energieeffizienzberatung“ ID: 50-159-1 der Landesanstalt für Landwirtschaft, Ernährung und Ländlichen Raum Baden-Württemberg, Online, 3.2.2021

Oechsner, H.:
Trace elements in biogasplants to compensate for substrate-related deficiencies – Incresing the process efficiency. In: Enhanced biogas production & recent innovations. Ege University, Izmir, 17. – 19. März 2021, Online

Oechsner, H. und Lijun Zhou:
Inactivation of different weed seeds in the biogas process at different fermentation temperatures and retention times. In: International conference on biotechnology for sustainable agriculture, environment and health (BSAEH-2021), Jaipur, Indien, Online, 4. – 8. April 2021

Oechsner, Hans:
Degredation efficiency of biogas plants, depending on substrate, hydraulic retention time and number of digesters in series. In: Biorestec-Online-Congress 2021, Session 2B: Biological waste treatment, Online, 17. Mai 2021

Oechsner, Hans:
Aufbereitungsverfahren für faserhaltige Substrate und Vergleich mit der neu entwickelten Kugelmühle. Biogas Infotage 2021, Renergie Allgäu e.V., Ulm, Hybridveranstaltung, 07.-08.07.2021

Oechsner, Hans, Matthias Franz:
Bewertung von innovativen Verfahren zur Gewinnung von Pflanzenfasern in regionaler Wertschöpfung zur Optimierung der Biogas-Verfahrenskette. Statusseminar Netzwerktreffen Bioökonomie. MLR Baden-Württemberg. 23. – 24. Juni 2021, Online

Oechsner, Hans:
Pretreatment of fibre-rhich substrates. In Progress in Biogas V, International Congress at the University of Hohenheim, IBBK, Online, 22. – 24. September 2021

Oechsner, Hans:
Degredation efficiency of biogas plants, depending on substrate, hydraulic retention time and number of digesters in series. Great Cycle Meeting – International symposium on agriculture and rural carbon. Neutralisation-contribution of biogas process. Chinese Agricultural University, Beijing, 23. – 26. September 2021, Online

Oechsner, Hans:
Biogas as an important element of an energy supply with renewable energy. In: International Sustainability Workshop (ISW 2021) Qatar University, Online, Hybrid, Doha, Katar, 26. – 27. Oktober 2021

Oechsner, H.:
Effizienz von Biogasanlagen. In: Fortbildung Basisqualifikation „Grundlagen der Energieeffizienzberatung“ ID: 50-159-1 der Landesanstalt für Landwirtschaft, Ernährung und Ländlichen Raum Baden-Württemberg, Online 15.12.2021

Ohnmacht, B., Lemmer, A., Oechser, H.
Investigating the mixing in a full-scale biogas plant, Progress in Biogas V, online, 22.-24.09.2021

Ohnmacht, B.; Lemmer, A.; Oechsner, H. und Kress, P.:
Optimierung des Betriebs und Designs von Rührwerken zur Senkung des Eigenstromverbrauchs von Biogasanlagen“, 7. FNR/KTBL-KONGRESS - Biogas in der Landwirtschaft – Stand und Perspektiven, online, 29.-30.09.2021,

Ohnmacht, B.
Energieeffizienz in der Biogaserzeugung – Schwerpunkt Rührtechnik, LEL-Fortbildung, online. 3.2.2021

Ohnmacht, B.
Energieeffizienz in der Biogaserzeugung – Schwerpunkt Rührtechnik, LEL-Fortbildung, online. 15.12.2021

Oskina, A., Ravi, P.P., Lemmer, A.
Continuous flow bio-electrochemical system for organic wastewater treatment: Steps for its practical implementation, Online, Progress in Biogass V – International online conference, 22-24.09.2021

Rubner, I., Baur, L., Grau, B., Steinbrenner, J., Hülsemann, B., Lemmer, A.
Curricular innovation research in the filed of renewable energy using the example of anaerobic digestion and methane production. (2021) 9th International Conference on Sustainability, Technology and Education

Steinbrenner, J., Lemmer, A.
Neue schlüsselfertige Güllekleinanlage? - Ergebnisse aus dem Kooperations
Projekt DEMETHA. (2021) 20. Süddeutsche Biogasfachtagung, Westerheim

Posters

Baumgart, M., Hülsemann, B.
Verfahrenstechnische Untersuchung zur Fasergewinnung aus Durchwachsener Silphie zur Papierherstellung bei gleichzeitiger energetischer Verwertung der aufgeschlossenen Pülpe. Biogas Infotage, Ulm, 7-8.7.2021

Brandhorst, C, Lemmer, A.
Naturnahe Bewirtschaftung von FFH-Mähwiesen für die Biogasproduktion. Methanerträge im Vegetationsverlauf. Biogas Infotage 2021, Renergie Allgäu e.V., Ulm, 07.-08.07.2021

Brandhorst, C, Lemmer, A.
Naturnahe Bewirtschaftung von FFH-Mähwiesen für die Biogasproduktion. Methanerträge im Vegetationsverlauf. Online Tagung „Biogas in der Landwirtschaft – Stand und Perspektiven“, FNR & KTBL, 29.-30.09.2021

Heller R., Hülsemann, B., Oechsner H.
Mechanische Desintegration lignocellulosehaltiger Substrate mit Hilfe einer Kugelmühle für die Flexibilisierung der Biogaserzeugung, Biogas Infotage, Ulm, 7-8.7.2021

Holl, E., Steinbrenner, J., Lemmer, A.
ProBioLNG – Innovative Prozesskette zur ressourceneffizienten Erzeugung von Bio-LNG. Biogas Infotage, Ulm, 7-8.7.2021

Holl, E., Steinbrenner, J., Lemmer, A.
Development of an innovative process chain generating resource efficient biofuel based on methane, BMBF project: ProBioLNG. Biorestec, Online, 17.05.2021

Hülsemann, B., Bidlingmaier, C.
Biogas Progressiv (538). Biogas Infotage, Ulm, 7-8.7.2021

Hülsemann, B., Oechsner, H.
Efficiency analysis of biological systems of biogas plants: definition and accuracy. Progress in Biogas, Online, 24.9.2021

Hülsemann, B., Lang, P.
Bewertung von innovativen Verfahren zur Gewinnung von Pflanzenfasern in regionaler Wertschöpfung zur Optimierung der Biogas-Verfahrenskette. Biogas Infotage, Ulm, 7-8.7.2021

Khan. M.T., Hülsemann, B., Krümpel, J., Oechsner, H., Lemmer, A.
Verwertung von Molkerei-Abwässern in Anaerob-Festbettreaktoren. Biogas Infotage, Ulm, 7-8.7.2021

Khan. M.T., Hülsemann, B., Krümpel, J., Oechsner, H., Lemmer, A.
Anaerober Abbau von Prozess-Abwässern aus der Hydroxymethylfurfural-Produktion. Biogas Infotage, Ulm, 7-8.7.2021

Ohnmacht, B., Krümpel, J., Lemmer, A.
Verbundprojekt „Sens-O-Mix“: Entwicklung und Erprobung sensorbasierter Rührsysteme in Biogasanlagen zur Steigerung der Effizienz und Prozessstabilität bei einer lastflexiblen und bedarfsgerechten Biogasproduktion. Biogas Infotage, Ulm, 7-8.7.2021

Oskina, A., Lemmer, A., Kruse, A.
Energetische und stoffliche Kopplung einer Biogasanlage mit einer Bioraffinerie. Biogas Infotage 2021, Renergie Allgäu e.V., Ulm, 07.-08.07.2021

Steinbrenner, J., Lemmer, A.
DEMETHA - De-Methanisierung von Flüssigmist - Intelligente Energieversorgung im ländlichen Raum durch flexible Energiebereitstellung mit Güllekleinanlagen. Biogas Infotage, Ulm, 7-8.7.2021

Lectures at other Universities or Universities of Applied Sciences

Lemmer, A.
Zukünftige Anforderungen an die Biogastechnik. (2021) Vorlesung an der Züricher Hochschule für Angewandte Wissenschaften (ZHAW), online Vorlesung, 09. Februar 2021

Other publications

FNR. Schlussbericht DEMETHA - De-Methanisierung von Flüssigmist - Intelligente Energieversorgung im ländlichen Raum durch flexible Energiebereitstellung mit Güllekleinanlagen (2021), verfassende Mitarbeiter: Steinbrenner, J., Lemmer, A.

FNR.
Biogas-Messprogramm III (2021), verfassende Mitarbeiter: Hülsemann B., Oechsner, H., ISBN-Nr.: 978-3-942147-42-2

KTBL
Gasdichte Lagerung von Rinder- und Schweinegülle – Eine Maßnahme zur Minderung und Vermeidung von klimarelevanten Emissionen aus der Wirtschaftsdüngerlagerung (2021), KTBL Schrift 525

KTBL.
Gasausbeute in landwirtschaftlichen Biogasanlagen – Potenziale, Erträge, Einflussfaktoren (2021), verfassende Mitarbeiter: Oechsner, H., B. Hülsemann und Weitere, KTBL-Schrift 526

KTBL
Biogasanlagen effizient betreiben – Bewertungskriterien und -methoden. Darmstadt (2021), verfassende Mitarbeiter: Lemmer, A., KTBL Schrift 525

Martinez-Hernandez, C., Y. Garcia-Lopez, H. Oechsner
Biogas plants in Germany: Revision and Analysis. Revista CienciasTecnicas, ISSN 1010-2760, Vol. 30, No. 4, Oktober 2021, S. 88-100

Martinez-Hernandez, C., H. Oechsner, M. Brule
Hohenheim biogas yield test (HBT) Methodology for the determination of methane potential in agricultural substrates. Revision and Analysis. Revista CienciasTecnicas, ISSN 1010-2760, Vol. 30, No. 4, April 2021, S. 70-78

Oechsner, Hans
Keine Störenfriede in den Fermenter. Nachgefragt bei … In BW-agrar, Heft 19, 2021, S. 5

Projectvideos

ProBioLNG https://www.youtube.com/watch?v=zzMcwpycWUI&t=2s

PowerLand4.2 https://www.youtube.com/watch?v=wrRsbKZKGu4

BioSaiFle https://www.youtube.com/watch?v=RaLdjXVp8Mk

Websites

PowerLand4.2 https://www.powerland42.de/

Committee work

- Bioresource Technology: Mitglied im Editorial board
- MDPI: Special Issue Editor „Renewable Energy in Agriculture”
- KTBL – Arbeitsgemeinschaft „Energie“
- KTBL – Arbeitsgruppe „Ringversuche“
- KTBL – Arbeitsgruppe „nachhaltige Biogaserzeugung“
- KTBL – Arbeitsgruppe „Gasdichte Güllelagerung“
- KTBL – Arbeitsgruppe „Gaserträge“
- KTBL – Arbeitsgruppe „Güllevergärung“
- VDI-Richtlinie 4630 – Wissenschaftliches Komitee
- VDLUFA – Methodenkommission Biogasertrag, Restgaspotenzial
- DLG – Prüfungskommission „Separator“
- VERA – Internationale VERA Kommission für Gülleseparation
- Internationale Arbeitsgruppe „Methode Biogasertragsbestimmung“
- Verschiedene Tagungsausschüsse (z.B. VDI, KTBL, FNR, FV-Biogas, Progress in Biogas, Uni Stuttgart, Era-netmed, Doktorandenkolloquium)
- Projektbeiräte (Bio2020Plus, OptiSys, Subeval)

The State Institute of Agricultural Enginieering & 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
Elke Weiß (ALB)

Scientific Staff, Post-Docs
M.Sc. Konstantin Dinkler
M.Sc. Benedikt Hülsemann
Dr. sc. agr. Johannes Krümpel
M.Sc. Benjamin Ohnmacht
Dr. Anastasia Oskina
M.Sc. Gregor Sailer
M.Sc. Jörg Steinbrenner
Dr. sc. agr. Andrea Stockl

Docotral Candidates
M.Sc. Marian Baumgart
M.Sc. Christina Brandhorst
M.Sc. Celina Dittmer
M.Sc. Marion Gebhardt (extern)
M.Sc. René Heller
M.Sc. Elena Holl
M.Sc. Muhammad Tahir Khan
M.Sc. Ievgeniia Morozova
M.Sc. Leoni Neubauer
M.Sc. Katharina Schoder
M.Sc. Naga Sai Tejaswi Uppuluri

Doctoral theses are under the scientific supervision of:

- Prof. Dr. Joachim Müller
- PD Dr. Andreas Lemmer

Technical Staff
Ralph Drescher
Dipl.-Ing. agr. Christof Serve-Rieckmann

CT Assistants
Dipl.-Biol. Annette Buschmann
Jacqueline Kindermann

UNIVERSITÄT HOHENHEIM

LANDESANSTALT FÜR AGRARTECHNIK & BIOENERGIE (740)

Leiter der Landesanstalt

Dr. Hans Oechsner

Stellvertretender Leiter der Landesanstalt

PD Dr. Andreas Lemmer

Sekretariat

Margit Andratschke

Elke Weiß (ALB)

Wissenschaftliche Mitarbeiterinnen & Mitarbeiter

Dr. Anastasia Oskina

Projektleiterin
- Modellierung und Simulation
- Bioelektrochem. Systeme
- „NitroPhos“

Konstantin Dinkler

Projektleiter
- Nährstoffe im Biogasprozess
- Fachgebiets-administrator
- „BW2Pro“

Dr. Benedikt Hülsemann

Arbeitsgruppenleiter
- Praxisanlagen
- Substrataufbereitung
- Leitung HBT
- „ProBiogas“
- „BW2Pro“

Gregor Sailer

Wissenschaftlicher Mitarbeiter
- Hard- und Software
- „BW2Pro“

Dr. Johannes Krümpel

Arbeitsgruppenleiter
- Systemintegration
- Myzelbasierte Werkstoffe
- Messtechnik Labor
- Datenbank-management
- „Sens-O-Mix“

Benjamin Ohnmacht

Arbeitsgruppenleiter
- Flexibilisierung
- Rührsysteme
- Forschungs-biogasanlage
- „Sens-O-Mix“

Jörg Steinbrenner

Arbeitsgruppenleiter
- Zweistufige Vergärung
- Bio-CNG und Bio-LNG Produktion
- „Pro-BioLNG“

Dr. Andrea Stockl

Projektleiterin
- Konferenzen
- „BGA-Cluster“

Doktorandinnen & Doktoranden

Ievgeniia Morozova „Stickstoff“

Naga Sai Tejaswi Uppuluri „AMAIZE-P“

Nährstoffe im Biogasprozess

René Heller „FLEX-CRASH“

Optimierung von Praxisanlagen

Marian Baumgart „BW2Pro“

Marion Gebhardt (ext.) „Verbund-Faserstoffe“

Katharina Schoder „Fun2Fab“

Werkstoffe aus Rest- und Rohstoffen

Celina Dittmer „PowerLand 4.2“

Leoni Neubauer „i^2-Sens“

Christina Brandhorst „BioSaiFle“

Systemintegration der Bioenergie

Muhammad Tahir Khan „NeoBus“

Elena Holl „Pro-BioLNG“

Bio-CNG und Bio-LNG Erzeugung

Technische Mitarbeiterinnen & Mitarbeiter

Annette Buschmann

Jacqueline Kindermann

Christof Serve-Rieckmann

Ralph Drescher

Kontakt

Landesanstalt für Agrartechnik und Bioenergie (740)
Garbenstraße 9
70599 Stuttgart
Tel.: +49 (0)711 459 22683
Fax: +49 (0)711 459 22111

E-Mail: la740@uni-hohenheim.de

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

From left to right:

1st row: René Heller, Dr. Anastasia Oskina, Jacqueline Kindermann, PD Dr. Andreas Lemmer, Dr. Hans Oechsner, Christina Brandhorst, Annette Buschmann, Elena Holl, Dr. Andrea Stockl, Naga Sai Tejaswi Uppuluri

2nd row: Leoni Neubauer, Dr. Benedikt Hülsemann, Katharina Schoder, Dr. Johannes Krümpel, Jörg Steinbrenner, Ralph Drescher, Elke Weiß, Christof Serve-Rieckmann, Konstantin Dinkler, Marian Baumgart, Gregor Sailer