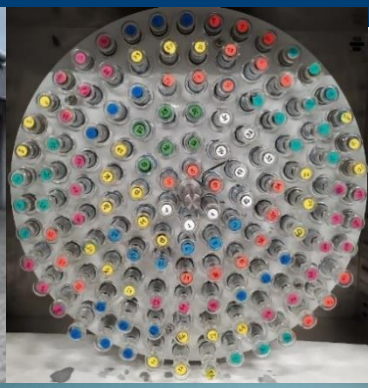
UNIVERSITÄT HOHENHEIM

LANDESANSTALT für Agrartechnik & Bioenergie

Annual Report 2022

State Institute of Agricultural Engineering and Bioenergy
University of Hohenheim



The State Institute of Agricultural Engineering and Bioenergy

The State Institute of 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 the agriculture in Baden-Wuerttemberg
- 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 State Institute has dedicated itself to special topics such as biogas production and questions of bioeconomy for many years, the aforementioned range of tasks has expanded considerably in recent years in the direction of university teaching. Due to the habilitation of PD Dr. Andreas Lemmer, some of the teaching tasks, in particular also the supervision of doctoral students, are now carried out directly by the State Institute, others jointly with the head of the institute Prof. Joachim Mueller. The teaching topic of biogas has become an integral part of the curricula for NAWARO (studies of biobased products and bioenergy) and agricultural science students. Students complete their bachelor's and master's theses as part of research projects and gain valuable research experience while working as research assistants at the State Institute. For the doctoral students employed at the State Institute, the mostly large and interdisciplinary research projects worked on with partners from other universities and research institutions and companies offer the opportunity to network, gain experience in scientific work and publish their results through publications in renowned international journals.

Thanks to the improvements in employee vaccination protection, further relief from Corona restrictions has been gradually implemented throughout the entire work. Since winter semester 2022/23, it was also possible to offer lectures in presence again. This significantly improved the possibility of direct interaction between lecturers and students.

In contrast to the domestic events and meetings, the international meetings are still largely limited to online meetings. For example, the events held as part of the large DFG research training group Amaize-P together with the CAU in Beijing took place only in online form. The almost regular visits of international scientists to the State Institute were also still largely interrupted. Staff participation in international congresses also usually took place via an online connection.

The staff of the State Institute is very active in preparing manuscripts for publication of excellent results in international journals. Thus, the international importance of the State Institute is constantly increasing and there are frequent requests for cooperation, exchange of scientists or joint applications for research projects. In addition, there are publications in agricultural weeklies or at national conferences for farmers and operators of biogas plants. In this way, the important findings from the research activities can be communicated in a practical and rapid manner to the users on-site and implemented there.

Russia's invasion of Ukraine in February 2022 and subsequent sanctions have led to a global energy crisis that has significantly increased the cost of fossil fuels. At the same time, in view of the noticeable climate changes, politicians and the public came to the conclusion that the expansion of renewable energies must be pushed further and that fossil energy must be dispensed with completely in the medium term. In this discussion, biogas also came into focus and was once again assessed as an important technology that can excellently complement fluctuating energy sources such as wind energy and PV power. Biogas has the advantage that, unlike other renewable energies, it can be produced in a targeted manner within certain limits and can also be stored temporarily.

Many works of the State Institute in recent years have addressed this issue and offer important insights into flexible biogas operation with flexible power generation, most of which have already been published in international journals or conference papers or research reports. Improving nutrient cycles is also gaining importance as energy prices rise.

When natural gas supplies from Russia ceased, there was a discussion of using biogas as a replacement. Today, biogas is converted into electricity and heat in a combined heat and power plant. If the heat is used to a large extent, this combination is probably the most efficient. However, for individual farms with a good location, e.g. near a forwarding agent, and a high proportion of manure in the substrate mixture, purifying the biogas and using it as fuel could also be an interesting option, offering new perspectives for farms in combination with the requirements of the European Renewable Energy Directive II (RED II). With the application of innovative fermentation systems such as two-phase fermentation, pressurized methanation and hydrogen methanation in a pilot plant for LNG and CNG production on a semi-industrial scale, the processes developed at the State Institute in recent years are being put on the road to practical application. In this context, studies on sensor technology, modeling and flexible biogas production are also carried out at the research biogas plant at the "Unterer Lindenhof" experimental station. The model project of the State Institute for the operation of a public city bus with biogas LNG will provide important data.

There are more and more political requirements that restrict the use of biobased resources for pure energy production. Therefore, the search for alternative substrates and by-products of food production continues to gain importance. The processing of difficult, high-fiber substrates by mechanical processing systems such as the ball mill should help to expand the substrate spectrum and enable their economic use. In addition to the purely energetic use of energy crops, the subject area of "bioeconomy" is becoming increasingly important in research. In some research projects of the State Institute, the production of fibers from permanent crops (e.g. *Silphium perfoliatum*) or from by-products, e.g. for paper production, plays an essential role and is investigated both in the laboratory and on a practical scale. The combination with biogas production makes it possible to test new digester concepts in practice. An extensive pilot project on this subject has been launched at the biowaste fermentation plant in Backnang, Germany, which is dedicated to processing the feedstock biowaste and converting it into various valuable materials (fibers, enzymes, platform chemicals, fertilizers) and biogas.

Only through the great commitment and the resulting excellent cooperation with the management and the team of the Unterer Lindenhof is the successful further development and testing of completely new technological approaches also 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 mostly quick support in the implementation of elaborate research-related 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 the highest motivation. By developing new strategies and transferring findings into practice, we are trying to strengthen and secure rural areas, the situation of farms and biogas plant operators in the long term. In doing so, we also focus on important developments for society as a whole in a time with 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 farmers, research and industry partners in Germany, but also worldwide.

Dr. Hans Oechsner

Head of the State Institut

Hohenheim Biogas Forum at the Biogas Info Days in Ulm

Dr. Andrea Stockl

PD Dr. Andreas Lemmer

The annual trade fair "Biogas Info Days" organized by 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 panels (science, practice and innovation) are a recurring and popular component of the Biogas Info Days. These panels are free of charge for both fair visitors and the exhibitors. Thus, the audience of the panels is composed of biogas plant operators, representatives of companies, authorities, associations, societies and scientists. This structure makes the Biogas Info Days ideally suited for transferring knowledge into agricultural practice.

The Hohenheim Biogas Forum at the Biogas Info Days 2022 is a two-day, single-session science panel in hybrid format (presence + online transmission) featuring a total of 12 presentations. It offers independent information to trade fair visitors on current research in the field of biogas. The panel was organized, moderated and thematically designed by the staff of the State Institute.

The project provided knowledge transfer from research to agricultural practice with a focus on the topic of biogas. Solutions and offers for supply security, grid stability and climate protection were examined in more detail. The following thematic blocks were identified as current focal points for the Hohenheim Biogas Forum and were covered by various presentations:

- Nutrient separation from digestate
- Biomethane mobility
- Demand-driven biogas production
- Fiber recovery

In addition to the lectures, the University of Hohenheim set up a scientific poster exhibition in the foyer of the fair. Here, 16 posters showcasing scientific projects on the topic of biogas were presented.

Poster exhibition and lectures at the Biogas Info Days in Ulm

Funding:

Federal Ministry of Food and Agriculture (FMFA)

Fachagentur Nachwachsende Rohstoffe e.V. (FNR)

Duration:

May 2022 - Dec. 2022

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 represents a new utilization path for biogas production. Since these substrates typically have high dry matter and lignin contents, special pre-treatment is required for utilization in biogas plants. Without this pre-treatment, the fermentation substrates are not completely and slowly degraded. This leads to low methane yields and results in uneconomical operation. Furthermore, process-related problems, such as increased floating layers and a higher stirring efforts in the fermenter, arise without pretreatment. Mechanical pretreatment by means of a ball mill can accelerate the kinetics of the degradation and gas formation process and increase the resulting methane yield of unused residues. Additionally, the process reliability and economic efficiency are enhanced. Therefore, it contributes 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 to efficiently process t lignocellulosic substrates 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 residues from agriculture in biogas plants attractive and potentially replace a part of the energy crops cultivated for biogas production. Furthermore, it would contribute to improving CO_2 footprint of the entire process chain and the sustainability of biogas plants.

Ball mill prototype at full-scale research biogas plant "Unterer Lindenhof"

In 2022, the ball mill was put into operation. In the preliminary test phase, the system was tested with different substrates under various operating settings. Furthermore, additional safety elements were constructed and implemented for both the housing and the sampling areas of the substrate pre-treatment plant. In the last quarter of the year, the ball mill transitioned from test operation to continuous operation and is now feeding digester 1 of the research biogas plant with pre-treated substrate.

A pre-treatment trial with an increased share of solid manure is planned for the coming year at the biogas plant, spanning a period of 6 months. In this trial, digester 1 will be fed with pre-treated substrate through the ball mill, whereas digester 2 will be fed with an equivalent amount of substrate with the same substrate composition in the form of the untreated material. The aim of the experiment is to assess the influence of the substrate treatment with the ball mill on the gas yield and the viscosity of the digesters.

Funding:

Fachagentur Nachwachsende Rohstoffe e.V. (FNR)

Federal Ministry of Food and Agriculture (FMFA)

Partners:

State Institute of Agricultural Engineering and Bioenergy, University of Hohenheim

Biokraft Energietechnik GmbH

Bio-Energie Heuberg GmbH & Co. KG

Duration:

Oct. 2020 - Jan. 2024

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 utilization 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 Energys (fRE) and the electricity and heat demand have a seasonal profile due to changing weather conditions. Seasonal variations in energy demand can be effectively addressed through the implementation of seasonally adapted biogas plants (BGPs). Especially for BGPs that are connected to the heating grid, the concept of seasonalization holds promise for the future, which we aim 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 deferred 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. In this context, 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 BGPs. Clippings from conservation areas have a favorable carbon footprint and do not compete for land. Since these sites depend on regular biomass extraction to maintain 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 third year of the project, two harvesting methods for collecting cuttings from meadow orchards were tested and monitored within the framework of a working time study. Additionally processing trials were carried out to handle the cuttings effectively. A seasonally modeled load profile was run on a practical scale with the research biogas plant. The process stability was evaluated and the maximum possible rates of increase in gas production were determined.

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 being thoroughly examined from ecological, economical and systemic perspectives in order to determine a transfer potential for the remaining federal states

Moving the orchards in the district of Reutlingen, Southwest Germany

Funding:

Federal Ministry of Food and Agriculture (FMFA)

Fachagentur Nachwachsende Rohstoffe e.V. (FNR)

Partners:

University of Stuttgart,

Institute for Energy Economics and Rational Use of Energy (IER)

Leibniz Institute for Agricultural Engineering and Bioeconomy e.V. (ATB) Potsdam

County / District Office Reutlingen

Landschaftserhaltungsverband 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 - Apr. 2023

Biowaste to Products (BW2Pro)

M. Sc. Konstantin Dinkler

Dr. Benedikt Hülsemann

M. Sc. Gregor Sailer

M. Sc. Marian Baumgart

Dr. Hans Oechsner

Funding:

Ministry of the Environment, Climate Protection and the Energy Sector BW

European Regional Development Fund (ERDF)

Partners:

University of Stuttgart (ISWA, IGVP, IKT, IER)

Fraunhofer IGB

HS Offenburg

ifeu gGmbH

Novis GmbH

BIOPRO BW GmbH

AWRM

Duration:

March 2022 - March 2024

Within the framework of BW2Pro, a modular biorefinery for the utilization of municipal biowaste is set up and operated on a pilot scale with a throughput of 1 metric ton per day. On the basis of the biowaste, high-quality products are to be provided for material use on one hand and for energy generation on the other. A main challenge is the complex composition of the biowaste used, which is caused, for example, by seasonal influences. The BW2Pro biorefinery will, therefore, be equipped with innovative technologies for the treatment of complex biowaste, which will make efficient recycling possible in the first place. These are a steam explosion (SE) and a high-load fermentation. In the SE, the biowaste is thermally treated under pressure and then abruptly depressurized. During this process, the cells in the biowaste burst open, allowing the cell fluids to escape while the fibers remain intact. A solid-liquid separation is executed afterward. The solid phase is turned into plant pots or composite materials and thereby recycled. Biogas is exclusively obtained from the liquid phase and produced in a two-stage high-load digestion process. This means that hydrolysis and methanogenesis take place separately in a hydrolysis reactor and a methane reactor. The process can be operated very flexibly and is capable of efficiently utilizing the produced liquids by generation of biogas on demand with high organic loading rates. The improved utilization of biowaste represents an important pillar for achieving a sustainable bioeconomy. The pilot biorefinery is currently being built on the site of the Rems-Murr district's waste fermentation plant and is scheduled to go into operation in June 2023. Additionally, as part of the project, a lab-scale SE system and six fixed-bed digesters are built, all of which are also expected to be operational in June 2023

BW2Pro approach for optimized valorization of municipal biowaste

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)

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 timeframe.

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 regarding stirring to date have primarily relied on experience and visual observations of 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 the 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 assess the stirring requirements of the plant during constant and load-flexible operation. Self-learning methods are applied to identify suitable parameters for the stirrer control and to quantify the influence of the process parameters on the methane yield. The existing models for predicting (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 the commissioning of the sensor system and the creation of the control algorithms, the next step will be the long-term test operation at the research biogas plant.

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.

Dipl.-Ing. Benjamin Ohnmacht

Dr. Johannes Krümpel

PD Dr. Andreas Lemmer

Funding:

Fachagentur Nachwachsende Rohstoffe e.V. (FNR)

Federal Ministry of Food and Agriculture (FMFA)

Partners:

Fraunhofer IKTS
TU Berlin
HZDR
DBFZ
RTO

Duration:

May 2020 - Oct. 2023

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

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 transition requires a reliable forecast of the biogas demand as well as 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" led by 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, to respond proactively to critical conditions that may arise during highly flexible feeding. For this purpose, complementary measuring techniques for high temporal-resolution and accurate measurements of the biogas composition are to be used within the framework of i²-Sens. Based on these parameters, conclusions on process stability and efficiency will be drawn and integrated into the existing models for flexible feeding.

The measurement technology developed in the project is located in an air-conditioned measurement van, which was installed at the research biogas plant at Unterer Lindenhof in the summer of 2022. Currently, the measurement van is equipped with gas analyzers (infrared and UV spectrometers, electrochemical sensors), which are used to determine the biogas components with high temporal resolution. In the course of the project, further measurement technology will be installed. The first tests on load-flexible operation started in the autumn of 2022. The aim of these trials is to investigate the influence of feeding frequency on process stability.

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

Funding:

Fachagentur Nachwachsende Rohstoffe e.V. (FNR)

Federal Ministry of Food and Agriculture (FMFA)

Partner:

Union Instruments GmbH

Grant No.:

2220NR092A

Duration:

Aug. 2021 - July 2024

Measurement of gas components directly at the fermenters with new sensor technology. The installed UV spectrometer can be seen on the right

Innovative process chain for the resource-efficient production of Bio-LNG (ProBioLNG)

M. Sc. Elena Holl

Dr. Jörg Steinbrenner

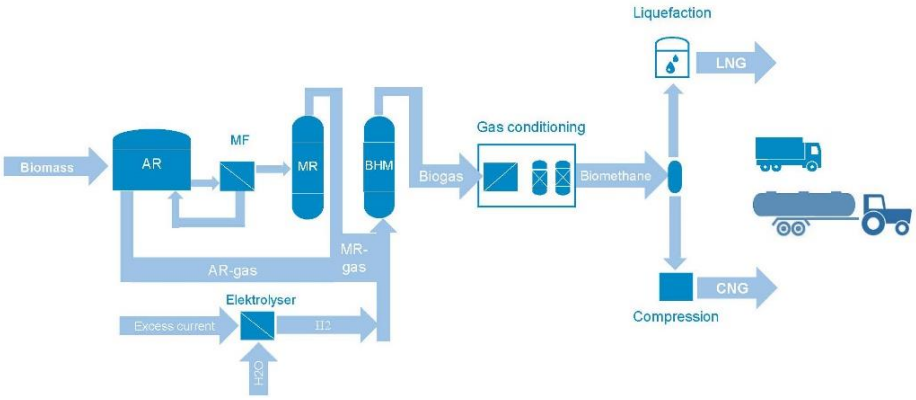
PD Dr. Andreas Lemmer

The reduction of CO_2-emissions in the industrial as well as private sectors 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 integrate, biological fuels are a competitive alternative to fossil fuels. In this case, using Bio-CNG (compressed biomethane) or Bio-LNG (liquified biomethane) from renewable resources 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 using application-oriented fundamental research. These biomethane-based fuels can thereafter be used as liquified Bio-LNG in the heavy transport, shipping, construction and agricultural sectors. For this purpose, individuals from science and economy incorporate their engagement to link proven and completely new technologies creating an innovative process chain.

The whole research project is managed by the State Institute 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 pressurized fermentation are conducted in the laboratory as well as pilot plant scale. Therefore a demonstration plant is developed and erected 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 third year of the project, all components of the pilot plant were delivered to the plant site and the construction of the infrastructure started. Furthermore, with the help of the project's own PR campaign, reports on biogas in general as well as project-specific content were published.



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

Funding:

Projektträger Jülich (PtJ)

Federal Ministry of Education and Research

Partners:

DVGW-EBI: Gas Technology Division

DVGW-EBI: Water chemistry division

KIT, Mobima

Air Liquide Forschung und Entwicklung GmbH

Claas Selbstfahrende Erntemaschinen GmbH

Liquind 24/7 GmbH

Duration:

Sep. 2019 - Aug. 2023

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

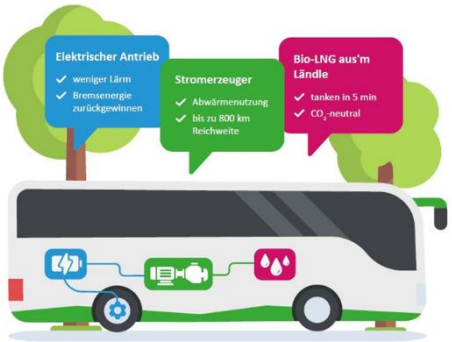
PD Dr. Andreas Lemmer

The reduction of CO_2-emissions in the industrial as well as private sectors 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 the required standards and be produced locally in sufficient quantities.

The 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 CO_2 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, an 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 acquisition 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

In the first project year, the components of the pilot plant for the production of bio-LNG were installed at the site. Furthermore, the work on the infrastructure was continued. The procurement of a mobile LNG filling station was discarded due to supply bottlenecks and the bus will now be refueled directly at the LNG station. Preliminary work has also been done on the technical validation of the facility based on RED2. A LinkedIn channel is being used to draw attention to the progress and benefits of the project.



Simplified illustration of the generator-electric drive of the LNG bus with its advantages

Funding:

Projektträger Jülich (PtJ)

Ministry of Food, Rural Areas and Consumer Protection Baden-Württemberg

(VDI/VDE/IT)

Partners:

Lauer&Weiss GmbH

Bottenschein Reisen GmbH

Duelli Energie GbR

Omnibusverkehr Bühler GmbH & Co. KG

Duration:

Oct. 2021 - Aug. 2023

Development of innovative concepts for the clustering of existing biogas plants for the provision of biomethane (BGA-Cluster)

Dr. Andrea Stockl

PD Dr. Andreas Lemmer

The number of biogas plants commissioned in Baden-Württemberg was concentrated in the years 2005 to 2011.

The expiration of the subsidies from the EEG after 20 years forced many biogas plant operators to reconsider and re-evaluate their plant capacities, combined with the search for new utilization possibilities. The continued operation of many biogas plants after 2024 is uncertain for many operators.

Within the scope of this project, measures that can be implemented in short- and mid-term will be identified to cluster existing biogas plants for the provision of biomethane. In addition, recommendations of action for plant operators will be developed. To conduct a detailed analysis based on practical data, a total of three suitable locations for the clustering of biogas plants will be selected and examined in more detail during the course of the project. The results will be funneled into a guideline for the clustering of biogas plants, which will provide decision support for political decision-makers, companies and biogas plant operators. A potential future utilization path for existing biogas plants may be the merger of several small BGAs, with a central upgrading plant to provide biomethane. In Germany, there are currently about 9600 BGA, but only about 220 biomethane upgrading plants.

In the first step, locations were selected and the local biogas plant operators were contacted. Information events were conducted to introduce the project. In three clusters across Germany, individual plants are being planned and analyzed in detail to find ecological and economic estimates for their profitable continued operation. The selected BGAs are currently being investigated financially, technologically and in terms of regulation for feasibility and subsequent marketing channels.

The State Institute is responsible for evaluating the technical upgrades of different types of BGAs after several years of operation, and also for contacting operators of BGAs within the potential clusters.

Biomethane upgrading plant (Erdgas Südwest)

Funding:

Fachagentur Nachwachsende Rohstoffe e.V. (FNR)

Grant No.:

2220NR157B

Partners:

DVGW
Engler Bunte Institut

Erdgas Südwest

Fachverband Biogas

Keep it green

Grinix

Duration:

Nov. 2021 - Jan. 2024

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 state fermentation (TS >20%), which is more technically suitable, currently has uneconomical power generation costs of >20 cents/kWhel for small plants.

A solid matter digester with investment costs below 8,000 €/kWhel. is to be developed 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, regional use of the residual materials as well as the implementation of the 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 plant is under construction. The construction will end by the middle of 2023.

Funding:

Federal Ministry of Economics and Energy

Projektträger Jülich (PtJ)

Partners:

IZES Ltd.

Ökobit Ltd.

Duration:

Jan. 2020 - Dec. 2023

Solids fermentation plant (Pertagnol, 2019)

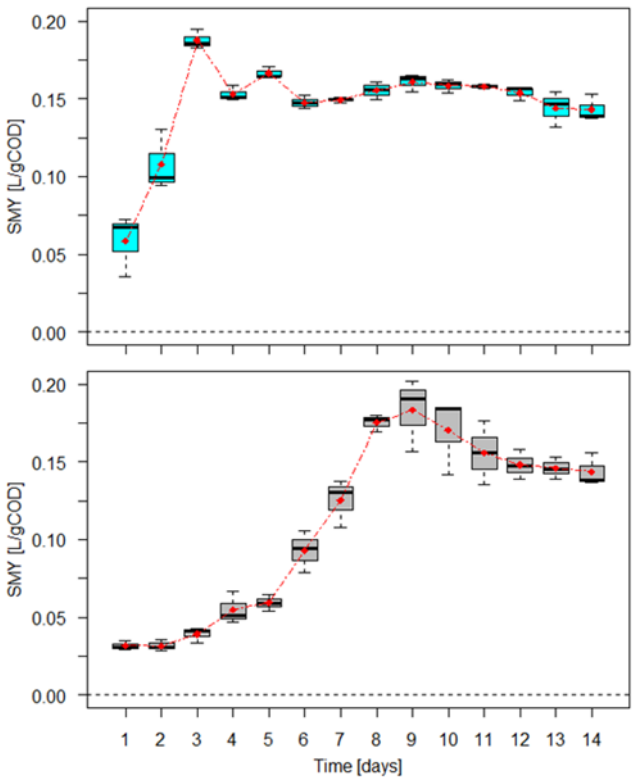
GRowing Advanced industrial Crops on marginal lands for biorEfineries (GRACE)

The BBI demonstration project “GRowing Advanced industrial Crops on marginal lands for biorEfineries” (GRACE) is a 15 million € project, that 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, while ensuring a reliable and affordable supply of sustainably produced biomass, and to better link biomass producers with the processing industry. 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 contributing to a sustainable and closed-loop system..



Daily specific methane yields for 10g COD/L of Hydroxymethylfurfural process-wastewater at thermophilic (top) and mesophilic (bottom) temperatures in continuously operated fixed bed reactors

M. Sc. M. Tahir Khan

Dr. Johannes Krümpel

PD Dr. Andreas Lemmer

Funding:

Bio-based Industries Joint Undertaking (BBI JU)

Partners:

Wageningen University
INRA
Aberythwyth University
Università Cattolica del Sacro Cuore
University of Zagreb
Novamont S.p.A.
Mogu S.r.l.
AVA Biochem BSL AG
Addiplast SAS
INA d.d.
Indena S.p.A
Consorzio di Bonifica di Piacenza
Gießereitechnik Kuehn
Fibranova S.r.l
Miscanthusgroep u.a.
Terravesta
Vandinter-Semo B.V.
NovaBiom
Johannes Furtlehner
Cluster SPRING

Duration:

June 2017 - Nov. 2022

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

Dr. Benedikt Hülsemann

M.Sc. Muhammad Tahir Khan

Dr. Johannes Krümpel

Dr. Hans Oechsner

During the production of yoghurt in the dairy industry, there is a residue rich in organics, which largely consists of rinsing water, whey and the washing water from the cup press. This residue can represent an interesting and cost-effective alternative to the conventional 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 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 analyses of the inflow and outflow.

Partner & Funding:

KWA Contracting AG

Duration:

Oct. 2020 - Jan. 2021

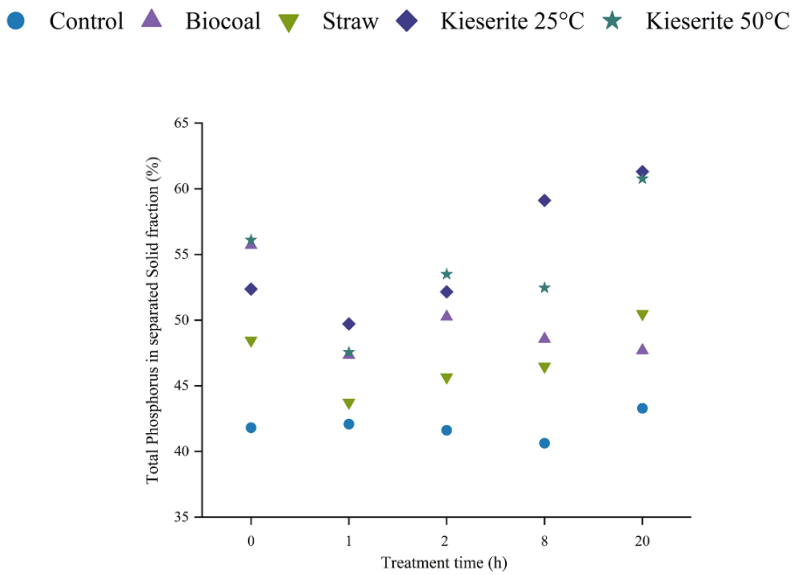
Substrate preparation, i.e. filtration of the dairy wastewater (left) and deposition of undegraded substances on the liquid surface of the reactor (right)

International Research Training Group "Adaptation of maize-based food-feed-energy systems to limited phosphate resources" (AMAIZE – P)

The international research training group (AMAIZE-P) has researchers participating from eleven departments of the University of Hohenheim and the China Agricultural University in Beijing. The goal of the project is to maximize phosphate use efficiency. To achieve this goal research is being carried out in the areas of plant breeding, plant cultivation, animal feeding, human nutrition, nutrient recovery through anaerobic digestion and hydrothermal carbonization systems, as well as economic analysis. The State Institute of Agricultural Engineering and Bioenergy is involved in research subject 3.3.

The focus of research subject 3.3 is to analyze the effect of limited phosphate fertilizer supply in agricultural systems and to optimize phosphate utilization efficiency by providing additional phosphate streams. Since digestate is a rich source of nutrients, in this study digestate was used as a substrate to recover nutrients. The research is now structured to recover phosphorus from anaerobic digestion systems using low and high-technology approaches. The focus was first given to a low-technology approach in which the digestate is treated with additives followed by solid-liquid separation.

Currently, the parameters of temperature and treatment time were tested to study their effect on the recovery of phosphorus. The separation efficiency was evaluated based on the amount of total phosphorus bound to the solid phase of digestate after solid-liquid separation. In addition, the distribution of phosphate fractions was analyzed with Hedley fractionation. The preliminary results shown in the graphic below suggest that treatment with additives had a positive influence on recovering phosphorus from digestate. Especially, the treatment with kieserite resulted in nearly 40% increase in the recovered phosphorus in the solid phase compared to the control. Subsequently, different additive amounts and the effect of pH on the recovery will also be tested.



Distribution of Total phosphorus in the solid phase of digestate after treatment with kieserite, biocoal, and straw at 0 h, 1 h, 2 h, 8 h, and 20 h

Naga Sai Tejaswi Uppuluri

Xueling Ran

Dr. Hans Oechsner

Dr. Jianbin Guo

Funding:

German Research Foundation (GRF)

Funded by DFG Deutsche Forschungsgemeinschaft

328017493/GRK 2366

Partner:

11 Institutes in Hohenheim, 11 Institutes of China Agricultural University

Duration:

Oct. 2018 - Sept. 2027

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

Dr.-Ing. Anastasia Oskina

M. Sc. Konstantin Dinkler

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 process combination for the separation of ammonium-nitrogen and phosphate from the fermentation residues of biogas. Ammonium nitrogen and phosphate are to be converted into highly concentrated, mineral fertilizer products with high transportability. The aim is to extend the biogas plant functionality to nutrient management and fertilizer-producing units.

As a first step, biochar and kieserite were added to digestate as additives for phosphate removal. The results showed that the treatment of digestate with additives resulted in a significant increase in P removal to the solid phase (21.7% compared to the control). The treated digestate was processed in microbial electrolysis cells (MEC) to test phosphate precipitation in the form of magnesium ammonium phosphate (MAP). The elevated pH in the cell creates optimal conditions for MAP formation: kieserite had shown better results compared to biochar. However, in both cases, only a small amount of MAP was removed from the tested substrate.

Further substrate treatment with CO_2 and NH_3 (32%) revealed the following aspects for the practical application of the conducted experiments: 1. Moderate acidification by CO_2 treatment of the digestate mobilized water-soluble and labile phosphorus from the solid to the liquid phase of the substrate (H_2O soluble phosphorus: 2.65 ± 0.46 g kg^{-1}_{TM} at pH 6.5 and 2.32 ± 0.60 g kg^{-1}_{TM} at pH 7.5 in control); 2. Increasing pH by NH_3 treatment of digestate shifted the chemical equilibrium from dissolved phosphate to MAP and calcium phosphates. Higher pH led to better precipitation (H_2O soluble phosphorus: 1.54 ± 0.31 g kg^{-1}_{TM} at pH 11).

The experiments revealed that pH adjustment with CO_2 and NH_3 achieved the desired effects of liberation and precipitation of phosphates. This approach allows phosphates to be recovered from digestate specifically as fertilizer and to replace chemicals in existing processes. Treatment of the digestate in an MEC, on the other hand, proved to be impractical.

Funding:

Ministry of Food, Rural Areas and Consumer Protection Baden-Württemberg

Duration:

Nov. 2021 - July 2022

a)  b) 

MAP on the cathode surface after BES treatment (a) and experimental setup for CO_2 treatment of digestate (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

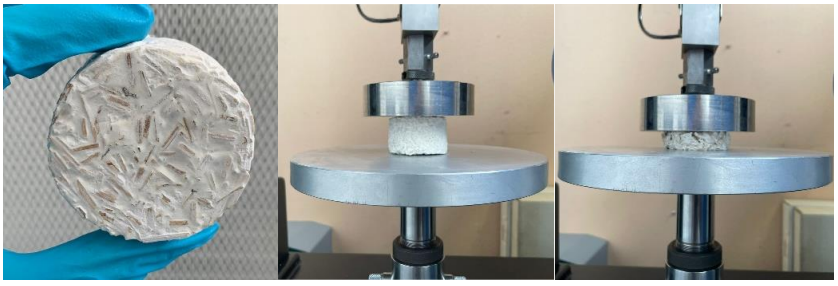
PD Dr. Andreas Lemmer

The current global waste problem is primarily caused by plastics produced based on fossil resources and are not biodegradable. Thus, on the one hand, greenhouse gases are emitted during production, which in turn drive climate change, and on the other hand, microplastics enter our ecosystems and, thus, in the long term, also our food cycle. Therefore, it is particularly essential to research new materials to replace products with a concise, helpful life. Packaging materials, in particular, should be mentioned here.

Mycelium materials have a high potential to be used as biobased and recyclable materials in the future. All lignocellulosic residues are available as starting substrates so that, among other things, inexpensive straw, husks and shives from food and fiber production that accumulates in large quantities can be upgraded. The fungi serves as a natural binder between the substrate particles, creating dimensionally stable materials with controllable properties.

The current work aims to establish the relationship between the substrate used and its particle size on the material properties. First, the compressive and flexural strength will be investigated to assess the suitability of the composites as packaging materials. In addition, optical changes of the composite are examined in relation to different post-processing methods. Finally, the materials can be evaluated based on their properties.

Subsequently, the materials will be tested for suitability for a circular economy. For this purpose, it is planned to return them to composite production or to test their degradability on a laboratory scale using anaerobic digestion. This will make it possible to determine how suitable the composites are for producing energy in the form of biomethane once they have been used. Overall, the goal is to reduce CO_2 emissions compared to conventional materials and close local material cycles.



Composite of shives from hemp and fungal mycelium (left), compression test of the materials to evaluate their mechanical properties (center and right)

Funding:
Vector Stiftung

Duration:
Sept. 2022 - Oct. 2024

Process engineering studies to optimize the silaging of continuous silphia to avoid faulty fermentation while achieving optimum fiber quality for papermaking - Silphie-Sil"

M. Sc. Marian Baumgart

Dr. Benedikt Hülsemann

Dr. Hans Oechsner

In order to increase the value added in rural areas, the Baden-Württemberg bio-economy initiative is looking for new or optimized ways of using agriculture. The use of energy crops such as the silphie plant for energy production is already established in Baden-Württemberg. Cultivation of the growing cup plant is particularly interesting because the perennial plant promises significant ecological advantages over corn. However, due to its high fiber content and the resulting low specific methane yield (approx. 250 L CH4/kg oTS), its fermentation is economically less competitive compared to corn (approx. 340 L CH4/kg oTS (KTBL,2013)). One reason is that the fibers cannot be degraded to methane in the biogas plant. With the help of thermal hydrolysis, a physical-thermal pre-treatment, these natural fibers can be separated and used as a high-quality product for paper production. The resulting liquid (pulp), along with the other cell components, is also highly fermentable.

It has been observed that the ensiling of cup plants as a chipping presents certain challenges. The lactic acid content of 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 produced 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 is being optimized in the laboratory with the inclusion of bacterial cultures and other additives to achieve a rapid pH drop, low ensiling losses, and a low-odor fiber product. The overall goal is to increase lactic acid formation in the silage and to reduce butyric acid formation, improve silage storage stability, reduce odor emissions, and increase biogas yield 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 studied. Fibers are then separated by thermal pressure hydrolysis and evaluated for potential use in papermaking (fiber quality, tensile strength, odor). The pulp is analyzed for methane potential and toxic substances (phenols, furfurals).

Funding:

Fachagentur Nachwachsende Rohstoffe e.V. (FNR)

Federal Ministry of Food and Agriculture

Partner:

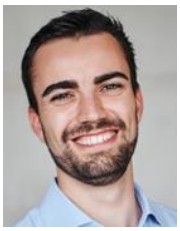
State Institute of Agricultural Engineering and Bioenergy, University of Hohenheim

Duration:

Nov. 2021 - July 2022

The first harvest date of Silphia stand (left) ensiled with the addition of ensiling aid (middle) and opening of waking jars after 90 days at the latest (right)

Utilization of renewable raw materials for biogas production and for the production of functional materials for textile and packaging applications (BigaTex)



M. Sc. Leonhard Lenz

Dr. Benedikt Hülsemann

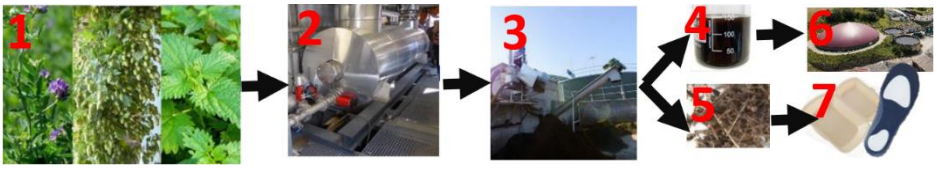
Dr. Hans Oechsner

The cascade use of fiber-rich residual materials and permanent crops such as hop grubbing chaff, alfalfa stalks and nettles as both fiber and biogas substrate offers an opportunity to increase the economic efficiency of biogas plants, conserve resources, increase regional added value and reduce greenhouse gas emissions. Separating the fibers that hardly degradable in the biogas process from the organic acids and saccharides that are degradable in the biogas process results in higher resource efficiency and another source of income. The separation is done by steam explosion pretreatment (STEX), a deflaker and a solid/liquid separator. This produces quality-enhanced fibers and a hydrolysate. Due to the different properties of the hydrolysate compared to conventional biogas plant substrates, fermentation in fixed bed reactors accelerated the gas formation rate and thus adds to an increase in economic efficiency. As a positive side effect of the harsh conditions of the STEX (approx. 160°C, 6 bar), there are hygienization effects that can counteract the spread of pathogens, such as the "citrus bark cracking viroid", and enable the use of the digestate as fertilizer. Malfermentation leads to lower methane yields and to odor formation that spreads into the fiber.

The aim of the project is to analyze and optimize the ensiling of the substrates (hop grubbing chaff, alfalfa stalks and stinging nettles) using different ensiling agents. Special focus will be placed on the formation of odor-intensive organic acids. Currently, a laboratory STEX is being set up for a more detailed investigation on the influence of temperature, pressure and residence time on the fiber and hydrolysate quality. The company Outlast Technologies GmbH and Hochschule der Medien will combine the fibers with functional additives in various processes such as the wet flow process and fiber casting process to produce shoe insoles and packaging materials.

Furthermore, a laboratory plant with fixed-bed reactors is currently being set up to test the hydrolysates with a low dry matter content for fast and effective fermentation.

With the optimized parameters, the STEX will be carried out in a pilot plant to compare the laboratory results with those of an industrial plant.Ultimately, material flow and energy balances will be analyzed to calculate the economic feasibility of the process.



Bioeconomy concept underlying the BigaTex project. Substrates (alfalfa stalks, hops grub, and stinging nettle) (1), STEX (2), separation (3), hydrolysate (4), fiber (5), biogas production (6), and material products such as shoe insoles and packaging materials (7). (Schematic diagram)

Funding:

Ministry of Food, Rural Areas and Consumer Protection Baden-Württemberg

Partners:

Institute for Agricultural Engineering University of Hohenheim

Outlast Technologies Ltd.

Hochschule der Medien Stuttgart

Duration:

Sept. 2022 - Aug. 2024

Increasing the share of slurry and other agricultural fractions utilised via anaerobic digestion as well as developing new strategies for biogas plants in order to preserve biogas production and to reduce greenhouse gas emissions from livestock farming (image campaign)

Dr. Manfred Dederer

Dr. Hans Oechsner

Currently, around 25% of farm manure is digested in biogas plants in Baden-Württemberg. To reduce emissions from agriculture, in particular from animal farming, anaerobic digestion is a very elegant and efficient method. Depending on the type of liquid manure it is possible to save between 20% and 59 % of greenhouse gases. Therefore, increasing anaerobic digestion of manure can contribute significantly to reducing GHG emissions from agriculture.

The project aims to describe the limitations in increasing the amount of manure in biogas plants. In addition, it will be investigated which legal requirements have to be implemented to increase the proportion in manure. Furthermore, concepts for new plants will be developed and established to set the ground for future sustainable development.

Funding:

Ministry of Food, Rural Areas and Consumer Protection Baden-Württemberg

Partner:

LAZBW Aulendorf

Duration:

Sept. 2022 - Aug. 2025

Biogas plant with processing of manure

Research biogas plant "Unterer Lindenhof"

PD Dr. Andreas Lemmer

Dipl.-Ing. Benjamin Ohnmacht

With the research biogas plant at Unterer Lindenhof in Eningen u.A., the University of Hohenheim and in particular, the State Institute for Agricultural Engineering and Bioenergy have a worldwide unique large-scale research biogas plant. With two main digesters, one secondary digester, one digestate storage as well as almost 1000 recorded measuring points and plant parameters, both practical and basic research-oriented questions can be dealt with. The main topics are the system integration of bioenergy, the utilization of organic residues as well as new process approaches for nutrient management and process control. For the third time in a row, the number of research projects carried out at or with the research biogas plant reached a record level:

- 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 biogas plants
- AMAIZE-P: Deployment of phosphate resources for nutrient recycling via anaerobic digestion systems
- emission" fuel
- NEObus - Negative Emission Public Transport
- i²-Sens: Development of innovative and intelligent sensors to ensure process stability during load-flexible operation of biogas plants

In addition to the research and its coordination, the State Institute for Agricultural Engineering and Bioenergy is also responsible for the operational management of the facility on behalf of the Rectorate. The successful operation of this complex research station is only possible due to the great personal commitment of the employees of the Experimental Station Agricultural Sciences and the State Institute. We would like to express our sincere thanks to all colleagues.

Research biogas plant of the University of Hohenheim at Unterer Lindenhof in Eningen u.A.

Hohenheim Biogas Yield Test (HBT)

Dr. Benedikt Hülsemann

Dr. Hans Oechsner

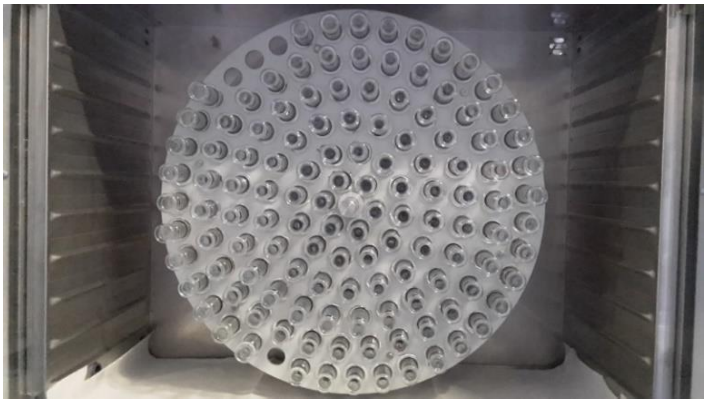
Biogas yield tests are used as a state-of-the-art method for the design of biogas plants. Substrates and digestate are tested for their methane and biogas potential. Furthermore, the methane content and the kinetics, i.e. the degradation over time, can be considered. The German regulation VDI 4630 is used in Hohenheim as a guideline for carrying out the tests.

At the State Institute for Agricultural Engineering and BioEnergy, the so-called Hohenheim Biogas Yield Test (HBT) is used for this purpose, which was also developed in-house. The advantage of the HBT is a low required sample quantity (400 mg TS) of the substrate with high accuracy at the same time.

In Hohenheim, 257 samples can be examined simultaneously in 3-fold repetition. A high reproducibility of the results is guaranteed by the use of two standards, which have been investigated since 2013. In addition, an inoculum is used, which is fed in adjacent 400 L laboratory reactors in a controlled manner at a low and constant level, to enable comparability of results. It is also possible to choose the temperature during fermentation.

High quality of the results is also ensured by participation in the KTBL round-robin test. So far, the certificate has been achieved in every year. Furthermore, the State Institute of Agricultural Engineering and Bioenergy also actively cooperates and leads the committee for the round-robin test, as well as the KTBL publication "Gas yield in agricultural biogas plants", in which standard values for methane potentials of various conventional substrates are presented.

The HBT is used in the context of various scientific projects and contract work with very different questions and substrates. In addition to the methane yield determination, the residual gas potential measurement and the emission potential determination carried out at 20°C also play an important role.



Climatic chamber (HBT) with 125 samples (left), single sample in glass flask (right)

Contact:

Benedikt.Huelsemann
@uni-hohenheim.de

+49 (0)711 459 23371

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

In the chemical laboratory of the State Institute of 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, 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.

Dipl.-Biol. Annette Buschmann

Jacqueline Kindermann

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.

Co-organized Conferences

ALB Fachtagung – „Automatisierung und Tierwohl in der Milchviehhaltung “
17. März 2022, Online Fachtagung, veranstaltet zusammen mit der ALB Baden-Württemberg

International Biogas & AD Training Course
22.02.-15.03.2022, Online-Kurs, veranstaltet zusammen mit dem IBBK

Hohenheimer Biogasforum auf den Biogas-Infotagen
08.-09. July 2022, Messe Ulm, veranstaltet in Kooperation mit dem renergie Allgäu e.V.

Beratungsstand am Landwirtschaftlichen Hauptfest in Stuttgart
25.09. – 03.10., Wasen, Bad-Cannstatt, Halle 1, zusammen mit der ALB Baden-Württemberg

International Biogas & AD Training Course
05.-14.09.2022, Online-Kurs, veranstaltet zusammen mit dem IBBK

ALB Fachgespräch - „Energieerzeugung und -nutzung im landwirtschaftlichen Betrieb - Autarkie, Effizienz, Einkommensquelle“
10. November 2022, Bauernhof Blumenstock, Kirchberg/Jagst, veranstaltet zusammen mit der ALB Baden-Württemberg

University examinations 2022

PhD theses

Hülsemann Benedikt
“Development and Evaluation of Methods for Assessing the Efficiency of Biogas Plants” 31.3.2022

Gebhardt Marion
“Characterisation of biogas digestate as raw material for fibre composites“ 24.11.2022

Morozova Ievgeiia
“Nitrogen-rich and lignocellulosic biomass for biogas production: methane yield potentials, process stability and nutrient management“ 20.12.2022

Bachelor and Master theses

Arz Christian
Machbarkeitsstudie zum Einsatz von Biomethan als Treibstoff in Bussen des regionalen ÖPNV. Projektarbeit. Betreuung: Elena Holl, Andreas Lemmer

Küver Ezgi
Untersuchungen der Fettsäuren-Zusammensetzung und Kinetik während des Biogasprozesses im HBT bei Vergärung von Substraten mit unterschiedlichen Nährstoffzusammensetzungen 10.10.2022 (Masterarbeit)

Kurz Franka
Arbeitszeit-Erfassungsstudie bei der Pflege von Streuobstwiesen. Projektarbeit. Betreuung Christina Brandhorst, Andreas Lemmer

Looney Annabella
Untersuchungen zur Materialbeschaffenheit von Mycel-Hanf-Kompositen in Abhängigkeit der Dauer des Wachstums“

Michel David
Optimierung der biologischen Wasserstoffmethanisierung zur Biomethanerzeugung aus Kohlenstoffdioxid (Bachelorarbeit)

Pollozek Luca
Planung einer BioEnergy-Forschungsanlage: Vom Basic-Engineering zur technischen Umsetzung. Forschungsprojekt. Betreuung: Elena Holl, Andreas Lemmer

Rink Robin
Optimierung der biologischen Wasserstoffmethanisierung zur Biomethanherstellung aus Rohbiogas (Bachelorarbeit)

Schimpl Max
Einfluss der Lagerung auf den spezifischen Methanertrag von Landschaftspflegematerial (Bachelorarbeit)

International Exchange

International Guests to the State Institute

Elviliana
Department of Agro-industrial Technology, Faculty of Agricultural Technology, Universitas Brawijaya, 8 Malang, Indonesia

Publications 2022

Peer-reviewed

Dittmer, C.; Ohnmacht, B.; Krümpel, J.; & Lemmer, A.
Model predictive control: Demand-Orientated, Load-Flexible, Full-Scale biogas production. Microorganisms, 10(4) doi:10.3390/microorganisms10040804

Ferrari, G.; Marinello, F.; Lemmer, A.; Ranzato, C.; Pezzuolo, A.
Network analysis for optimal biomethane plant location through a multidisciplinary approach. Journal of Cleaner Production, 378 https:/doi.org/10.1016/j.jclepro.2022.134484

Ferrari, G.; Holl, E.; Steinbrenner, J.; Pezzuolo, A.; Lemmer, A.
Environmental assessment of a two-stage high pressure anaerobic digestion process and biological upgrading as alternative process for biomethane production. Bioresource Technology 360, 2022, 127612, ISSN 0960-8524, https://doi.org/10.1016/j.biortech.2022.127612.

Gebhardt, M.; Milwich, M.; Lemmer, A.; Gresser, G. T.
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Conference proceeding posts

Oechsner, H., Hülsemann, B., Baumgart, M.:
Bioeconomic concept for the use of fibrous plants for joint material and energy use. International Conference on Biotechnology and Bioeconomic, BSBB-2022, 07.-11.12.2022, Guwahati, India, Abstract Book, p. 45 and 151

Final reports

Joint Project:

De-Methanization of Liquid Manure - Intelligent Energy Supply in Rural Areas through Flexible Energy Provision with Small-Scale Manure Plants (The report is in German)

Subproject 1: Coordination, Technical Foundations, and Environmental Impact
Subproject 2: Potentials, Legal Foundations, and Adaptation to Practical Operations
Subproject 3: Process Engineering Planning and Cost Estimation
https://www.fnr.de/ftp/pdf/berichte/2219NR130.pdf

Joint Project:

PowerLand 4.2 - Smart and innovative Land Power Systems (The report is in German)

Subproject 1: Forecast Models and Biogas Plant Control
Subproject 2: Algorithm-Based CHP Control
Subproject 3: Practical Integration in the Living Lab
https://www.fnr.de/ftp/pdf/berichte/22404717.pdf

Extraordinary events

Visit of Minister Cem Özdemir (Federal Minister of Food and Agriculture of the Federal Republic of Germany) to the State Institute of Agricultural Engineering and Bioenergy with a guided tour of the laboratories at the State Institute (including the biogas laboratory) on November, 2nd, 2022

Minister Cem Özdemir (left) and PD Dr. Andreas Lemmer (right) in the biogas laboratory of the State Institute of Agricultural Engineering and Bioenergy at the University of Hohenheim

Presentations

Baumgart, M.; Sailer, G.; Hülsemann, B.; Dinkler, K.; Oechsner, H.
Municipal biowaste as feedstock for combined generation of resources and energy through utilization in an innovative biorefinery. Sustainable Energy for a Sustainable Future, ASABE Conference. 24-27 October 2022. San Jose. Costa Rica.

Dinkler, K; Uppuluri, N.S.T.
Erste Ergebnisse der Separationsversuche mit Additiven 8.7.2022 Biogas Infotage Ulm

Heller, R.
FLEX-CRASH – Mechanische Desintegration lignocellulosehaltiger Substrate mit Hilfe einer Kugelmühle zur Substrataufbereitung und Flexibilisierung der Biogaserzeugung, Online, 6. Bayerische Biogasfachtagung, 9.-10.03.2022

Holl, E.
Erste Ergebnisse aus dem bioLNG Projekt 8.7.2022 Biogas Infotage Ulm

Hülsemann, B.
Fasergewinnung aus ökologischen und landwirtschaftlichen Substraten und Reststoffen 7.7.2022 Biogas Infotage Ulm

Hülsemann, B.
Grundlage und Einfluss der Biologie und die vorbeugenden Maßnahmen 29.11.2022 Grundkurs TRGS 529 und TRAS 120 rEnergy Allgäu e.V., Online

Hülsemann, B.
Bioeconomy concept for combined biogas and fiber production Sustainable Energy for a Sustainable Future, San Jose (Costa Rica), 24.10.2022

Hülsemann, B.
Noch 10 Jahre EEG – welche Optimierungsmaßnahmen können sich lohnen? – Beispiele aus Praxisbetrieben im Süden. Online 22.2.2022

Hülsemann, B.
Gewinnung von Pflanzenfasern in regionaler Wertschöpfung zur Optimierung der Biogas-Verfahrenskette, Bioökonomie Thementage des MLR 16.3.2022

Hülsemann, B.
Silphie als Biogassubstrat – Grundlagen und Optimierungs-Ansätze, Infoveranstaltung Silphie Regierungsbezirk Oberfranken 18.2.2022

Lemmer, A.; Ravi, P.P.
BGA-Cluster - Entwicklung von innovativen Konzepten zur Clusterung von Bestandsbiogasanlagen für die Bereitstellung von Biomethan. Kick-off meeting, online, 2022-02-02

Lemmer, A.; Holl, E., Steinbrenner, J.
Bio-CNG und bio-LNG: Verfügbare zero-emission Kraftstoffe für den Schwerlastverkehr und den ÖPNV. Bioökonomie Thementage Baden-Württemberg, 31.03.2022, Stuttgart

Lemmer, A.; Krümpel, J.
An introduction to Digester Biology. IBBK Biogas Online Training, Hohenheim, 2022-09-08

Lemmer, A.
On-Farm Bioraffinerien und Weiterentwicklung von Biogasanlagen – neue Perspektiven für die Landwirtschaft. 4. Bioökonomiekongress Baden-Württemberg 27.September 2022

Lemmer, A.; Oechsner, H.
Landesanstalt für Agrartechnik und BioEnergy: Von Biogasanlagen zu On-Farm Bioraffinerien. Agrartechnisches Seminar, Hohenheim, Oktober, 2022

Lemmer, A.; Oechsner, H.
Landesanstalt für Agrartechnik und BioEnergy: Von Biogasanlagen zu On-Farm Bioraffinerien. Besuch von Herrn Minister Czem Özdemir, 12. Oktober 2022

Lemmer, A.; Holl, E.
Biogas zur Erzeugung von Biomethan als Kraftstoff. Energyerzeugung und -nutzung im landwirtschaftlichen Betrieb - Autarkie, Effizienz, Einkommensquelle. Fachgespräch der ALB-BW am 10. November 2022, Kirchberg an der Jagst

Lemmer, A.
Mehr Biogas mit H2: Rieselbett schlägt Direkteindüsung. 9. BioEnergy-Forum der Biomasse Suisse, 30. August 2022, Solothurn, Schweiz

Lemmer, A.
Modellbasierte Fütterungssysteme für eine lastflexible Biogasproduktion 7.7.2022 Biogas Infotage Ulm

Lewerenz, S.; Sailer, G.; Pelz, S.; Lambrecht, H.
Life cycle assessment of biowaste treatment – Considering uncertainties in emission factors. 5th South East European Conference on Sustainable Development of Energy, Water and Environment Systems – SEE SDEWES. May 22-26 2022. Vlore. Albania.

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Möglichkeiten und Grenzen der Verwertung von Landschaftspflegegras in Biogasanlagen - BioEnergy aus der Landschaftspflege. In: Eigene Vielfalt. Gemeinsam zum Biotopverbund mit Naturschutz & Landwirtschaft“ - BioEnergy aus der Landschaftspflege. BUND Niedersachsen, 13. Oktober 2022 - Onlinevortrag

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Bioeconomic concept for the use of fibrous plants for joint material and energy use. International Forum on Industrial Bioprocess (IBA-IFIBiop) X International Forum on Industrial Bioprocesses, National Kaohsiung University of Science and Technology Nanzih Campus, Kaohsiung, Taiwan; October 27-30, 2022, Onlinevortrag

Oechsner, H., Hülsemann, B., Baumgart, M.:
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Oechsner, H.:
Kleegras als mögliches Substrat in landwirtschaftlichen Biogasanlagen. FNR-Fachgespräch „Co-Vergärung von Wirtschaftsdüngern mit Kleegras und weiteren Leguminosen-Gras-Mischungen“ am 29.9.2022 - Online

Oechsner, H.:
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Sailer, G.; Dinkler, K.; Baumgart, M.; Hülsemann, B.; Oechsner, H.
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Posters

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Verfahrenstechnische Untersuchungen zur Optimierung der Silierung von Durchwachsenen Silphie zur Verbesserung der anschließender Faserabtrennung und Papiererzeugung (SILPHIE – SIL). Biogas Infotage, Ulm, 6.-7.7.2022

Brandhorst, C.; Lemmer, A.
Naturnahe Bewirtschaftung von FFH-Mähwiesen für die Biogasproduktion, Methanerträge im Vegetationsverlauf. Biogas Infotage, Ulm, 6.-7.7.2022

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Nachhaltige Produkte aus Bioabfall Projekt „Biowaste to Products (BW2Pro)“. Biogas Infotage, Ulm, 6.-7.7.2022

Dinkler, K.; Oechsner, H.
Phosphatumwandlung durch anaerobe Vergärung, AMAYZE – P. Biogas Infotage, Ulm, 6.-7.7.2022

Heller, R.; Hülsemann, B.; Oechsner, H.
FLEX–CRASH, Mechanische Desintegration lignocellulosehaltiger Substrate mit Hilfe einer Kugelmühle für die Flexibilisierung der Biogaserzeugung. Biogas Infotage, Ulm, 6.-7.7.2022

Holl, E.; Lemmer, A.
Betrieb von Linienbussen mit on-Farm erzeugtem Bio-LNG und Bio-CNG NeoBus. Biogas Infotage, Ulm, 6.-7.7.2022

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Innovative Prozesskette zur ressourceneffizienten Erzeugung von Bio-LNG ProBioLNG. Biogas Infotage, Ulm, 6.-7.7.2022

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ALB Bioökonomie – kombinierte Biogas- und Faserproduktion 25.9-3.10.2022 Stuttgart, Bad Cannstadt

Hülsemann, B.; BidlingMayer, C.; Oechsner, H.
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Hülsemann, B.; Merkle, W.; Kress, P.
FeBio – Entwicklung und Bau einer kostengünstigen Feststoffbiogasanlage. Biogas Infotage, Ulm, 6.-7.7.2022

Hülsemann, B.; Lang, P.; Oechsner, H.
Bewertung von innovativen Verfahren zur Gewinnung von Pflanzenfasern in regionaler Wertschöpfung zur Optimierung der Biogas-Verfahrenskette. Biogas Infotage, Ulm, 6.-7.7.2022

Khan, M.T.; Krümpel, J.; Lemmer, A.
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Neubauer, L.; Ohnmacht, B.; Krümpel, J.; Lemmer, A.
i²–Sens Entwicklung innovativer und intelligenter Sensorsysteme zur Gewährleistung der biologischen Prozessstabilität beim lastflexiblen Betrieb von Biogasanlagen. Biogas Infotage, Ulm, 6.-7.7.2022

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ALB Flüssig- und Festmist für die Biogasanlage 25.9-3.10.2022 Stuttgart, Bad Cannstadt

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, 6.-7.7.2022

Oskina, A.; Dinkler; K.; Uppuluri, N.S.T.; Lemmer, A.
Kombinierte Rückgewinnung von N und P aus landwirtschaftlichen Gärresten NitroPhos. Biogas Infotage, Ulm, 6.-7.7.2022

Sailer, G.; Dinkler, K.; Baumgart, M.; Hülsemann, B.; Oechsner, H.
Biowaste to products (BW2Pro). Biogas Infotage, Ulm, 6.-7.7.2022

Stockl, A.; Lemmer, A.
BGA-Cluster, Entwicklung von innovativen Konzepten zur Clusterung von Bestandsbiogasanlagen für die Bereitstellung von Biomethan. Biogas Infotage, Ulm, 6.-7.7.2022

Lectures at other Universities or Universities of Applied Sciences

PD Dr. Andreas Lemmer

Lehrauftrag (SS) für das Modul „EE4.V2EE6.V2 Biogas-Prozesstechnik“ an der Hochschule Rottenburg.
Planung, Durchführung und Prüfung der gesamten Lehrveranstaltung (4 SWS)

Other publications

Brandhorst, Ch.; Lemmer, A.
Schützen durch Nützen; Fachbericht: BWagrar Schwäbischer Bauer, 74. Jahrgang, 19.2022, Verlag Eugen Ulmer

Carlos M. Martínez Hernándezl, Hans Oechsner, Adianni González Freirel:

Preparation of Animal Food in Germany. Revista Ciencias Técnicas Agropecuarias, Vol. 31, No. 2, April-June 2022, P. 1-6, E-ISSN: 2071-0054

Effenberger, M.; Lemmer, A.; Loewen, A.; Strobl, M.; Eckel, H.; Paterson, M.; Schmehl, H.
KTBL-Schrift 525 Biogasanlagen effizient betreiben - Bewertungskriterien und -methoden. Darmstadt, 2021, 84 S., 21 Euro, ISBN 978-3-945088-84-5 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen] , Best.-Nr. 11525.

Holl, E.; Müller, C.; Staudt, C.; Mörs, F.; Pratofiorito, G.; Pult, F.; Becker, S.; Geimer, M.; Wohlfahrt, F.; Pontzen, F.
Bereitstellung von methanbasierten Kraftstoffen aus biogenen Abfällen für Landmaschinen und den Schwerlastverkehr: Innovative Prozesskette zur Herstellung von ressourcen-effizienten methanbasierten Bio-Kraftstoffen gwf Gas + Energy, Jahrgang 163, 9 2022, ISSN 2366-9594, Vulkan Verlag, S.60-73

Lemmer, A.; Krümpel, J.
Biogasanlagen: Schlüsseltechnologie der Energywende. BW-agrar, Verlag Eugen Ulmer, Stuttgart

Awards

Holl, E.

Nomination for the 2022 German Gas Industry Innovation Award in the Sustainable Generation category

Projectvideos

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

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

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

Websites

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

Committee work

- Bioresource Technology: Member of the Editorial board
- MDPI: Special Issue Editor “Renewable Energy in Agriculture”
- KTBL – “Working group Energy“
- KTBL – Working Group “Interlaboratory Tests“
- KTBL – Working Group “Sustainable biogas production“
- KTBL – Working Group “Gas yields“
- KTBL – Working Group “Manure digestion“
- VDI Guideline 4630 - Scientific Committee
- VDLUFA – Methodology Commission Biogas Yield, Residual Gas Potential
- DLG – Examination committee “Separator“
- VERA – International VERA Commission for Manure Separation
- International Working Group ”Method Biogas Yield Determination“
- Various conference committees (e.g. VDI, KTBL, FNR, FV-Biogas, Progress in Biogas, Uni Stuttgart, Doctoral Colloquium)
- Project Advisory Councils (Bio2020Plus, OptiSys, Subeval)

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Katharina Schoder
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Leoni Neubauer
„i²-Sens“

System Integration of Bioenergy

Muhammad Tahir Khan
„NeoBus“

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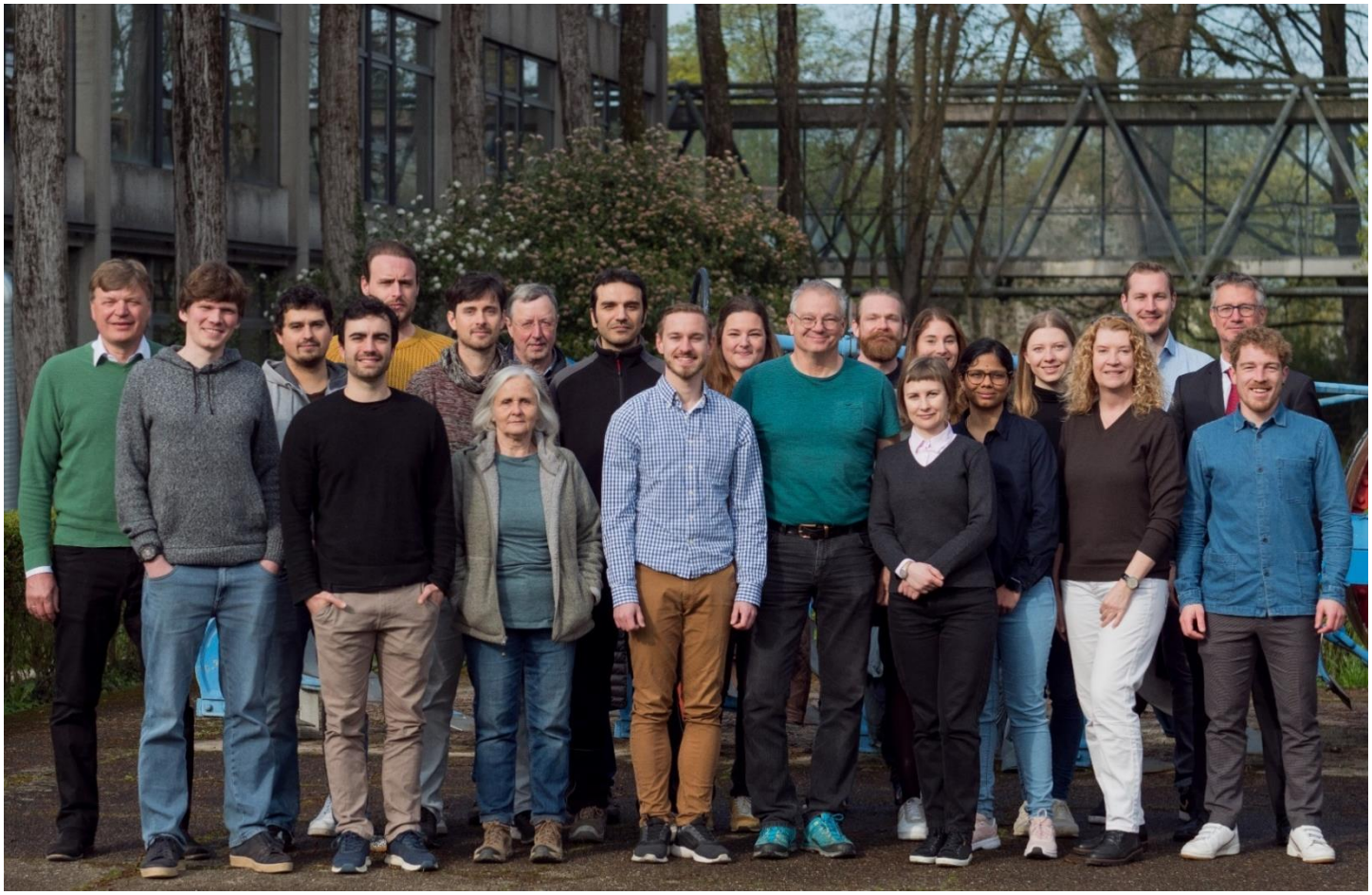

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