Course Concept: Two-Week Intensive Course on Biogas Processes and Bio-Process Engineering

Target Audience: International students with a scientific background

Course Duration: 14 days (2 weeks)

Course Language: German/English

Approach and Didactic Concept

The design of this two-week intensive course follows a progressive learning approach that combines theoretical fundamentals with intensive practical laboratory work. Students are gradually guided from the basics of biomass characterization through standardized laboratory methods to advanced process engineering techniques and cutting-edge technologies such as AI-supported process control. Students not only acquire theoretical knowledge but are also empowered through practical exercises to independently plan, execute, and optimize biogas processes.

Didactic Principles

The course design adheres to the following didactic principles:

Hands-on Approach: From the third day onward, students work intensively in the laboratory and conduct experiments independently. This ensures a strong practical orientation and promotes a deep understanding of the processes.

From Simple to Complex: The course begins with fundamental concepts of biomass characterization and progresses through standardized batch experiments to complex continuous fermentation processes and multi-stage procedures.

Integration of Theory and Practice: Every theoretical input is complemented by practical applications. The students not only learn the theory of VDI-4630 but also conduct the experiments themselves.

Future Orientation: The course integrates current research topics such as AI-supported process optimization, material utilization of biomass, and decentralized energy systems.

International Perspective: By incorporating international research approaches and discussing global application possibilities (e.g., Ukraine as a bioplastic producer), the course gains international relevance.

Detailed Course Outline

Week 1: Fundamentals, Laboratory, and Process Understanding

The first week lays the foundation for understanding biogas technology and imparts the necessary practical skills for laboratory work.

Day 1: Fundamentals of Biomass and Biogas Technology

Teaching Content:

On the first day, students are introduced to the world of biogas technology. After a welcome and presentation of the Company, they receive an overview of the different types of biomass and their characterization. The KTBL calculation methods are presented to assess the energetic potential of various substrates.

A central component is the introduction to the phases of anaerobic degradation: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. Students learn the microbiological fundamentals and understand how different bacterial strains collaborate to produce biogas from complex biomass.

The institute's innovative TRIPPLE-S process is presented, as well as the concepts of BLUE OIL (the liquid fraction after solid-liquid separation) and GREEN OIL (the acetic acid fraction after E-SYNTH hydrolysis). The students receive an overview of the entire process chain of the GREEN OIL Factory, from biomass to high-purity biomethane.

Problems in biogas production are discussed, as well as optimization possibilities through two-phase systems and alternative material utilization pathways.

Learning objectives:

- Introduction to biogas and biomass
- Characterization of biomass for the biogas process
- Phases of anaerobic degradation, problems and optimization possibilities, two-phase systems, material utilization pathways

Day 2: The Biogas Laboratory – theoretical intensive training

Course content:

The second day is dedicated to preparation for intensive laboratory work. The students are familiarized with VDI 4630, the central guideline for determining the biogas potential of substrates. The various analytical methods are discussed in detail.

A special focus is placed on carbon balancing, a key tool for evaluating process efficiency. The students learn how the degree of biomass degradation can be determined through balancing carbon flows.

The laboratory equipment is introduced: pH meters, dry matter determination devices, photometers for COD measurements, gas chromatographs, and gas volume measurement devices. A comprehensive safety briefing is conducted to prepare the students for practical work.

Learning Objectives:

- Intensive Training: VDI 4630 Methods for Biogas Laboratories
- Biomass and Biogas Laboratory Analytics Fundamentals
- Methods for Carbon Balancing in Experimental Setups

Day 3: Practical Training Part 1 – Fundamentals of Laboratory Analytics

Course Content:

From the third day onward, intensive practical work begins. The students independently perform basic analyses:

FOS/TAC Determination: The measurement of volatile organic acids (FOS) and total alkalinity capacity (TAC) is an important indicator of process stability. Students learn the titration method and the interpretation of FOS/TAC ratios.

pH Measurement: The correct measurement and interpretation of pH values is fundamental for process monitoring.

TS/oTS Determination: The determination of dry matter (TS) and organic dry matter (oTS) is essential for the characterization of substrates and the calculation of degradation rates.

The students learn how to prepare a substrate batch and store it properly to ensure reproducible experimental conditions.

In the afternoon, an excursion to the Jena wastewater treatment plant takes place, where the students collect inoculum (digested sludge) for their batch experiments. They also learn about the operation of a wastewater treatment plant and understand the importance of anaerobic sludge treatment.

The students are able to independently perform basic laboratory analyses and evaluate the results. They understand the importance of correct sample preparation and storage. They learn the practical significance of inoculum for fermentation experiments.

Learning Objectives:

- Visit to Jena wastewater treatment plant – Collection of inoculum for batch experiments, maize silage
- Practical training: Conducting FOS/TAC, pH, TS/oTS analyses
- Fundamentals of evaluation and execution of laboratory fermentation experiments
- Preparation of substrate batch, substrate storage for experiments

Day 4: Practical Training Part 2 – Batch Experiments

Topic: Conducting batch experiments according to VDI 4630

Teaching Content:

The fourth day is dedicated to conducting standardized batch experiments. The students set up their own batch assays according to VDI 4630, mixing various substrates (e.g., maize silage) with the inoculum obtained the previous day.

Gas analysis is introduced: students learn how to determine gas composition using gas chromatography and how to correctly measure gas volumes. The significance of the different gas components (CH_4, CO_2, H_2, H_2S) is discussed.

Photometric measurement is introduced, particularly for the determination of organic acids and chemical oxygen demand (COD). Students perform initial COD measurements and learn about the importance of this parameter for process monitoring.

An introduction to the microbiology of the biogas process concludes the day. Students become familiar with the main microbial groups and understand their roles in anaerobic degradation.

Students begin using a specialized evaluation template for data collection, which they will use throughout the course to document their experiments.

Learning Objectives:

- Practical training: conducting batch experiments according to VDI 4630
- Supervision of experiments using the evaluation template for data collection (batch experiments, hydrolysis/acidogenesis, continuous digestion tests)
- Introduction: gas analysis and gas volume measurement
- Introduction: photometric measurement (organic acids, COD, etc.)
- Microbiology in the biogas laboratory – introduction

Day 5: Practical Training Part 3 – Laboratory Reactors and Process Start-up

Topic: Introduction to Continuous Fermentation Processes

Course Content:

On the fifth day, students are introduced to laboratory reactors. They learn about the technology and maintenance of fermenters, including agitators, heating systems, pH control, and gas detection systems.

Students prepare the setup for continuous experiments. Unlike batch experiments, continuous systems are regularly fed and digestate is removed, allowing for a more realistic simulation of biogas plants.

Data acquisition and analysis using specialized software are further developed. Students learn how to digitally capture, visualize, and evaluate process parameters.

The supervision of the batch experiments initiated the previous day continues, and initial gas measurements are conducted.

Learning Objectives:

Students become familiar with the operation of laboratory reactors. They are able to start and monitor continuous fermentation processes. They master the use of digital process control and data acquisition.

Week 2: Deepening, Plant Engineering, and Future Technologies

The second week deepens knowledge of advanced process engineering techniques, integrates plant engineering and excursions, and presents pioneering technologies.

Day 6: Excursion and Data Analysis

Topic: Practical experience at a real biogas plant

Course Content:

The sixth day begins with an excursion to a biogas plant in the Jena region. Students experience a plant in real operation and can link their theoretical knowledge with practical application. During the tour, all essential components are explained: substrate reception, pre-tank, fermenter, gas storage, combined heat and power unit (CHP), and digestate storage.

Students conduct data collection and take samples of substrate, fermenter content, and digestate. These samples are later analyzed in the laboratory.

Back in the laboratory, the operational parameters of the plant are calculated: substrate mixture, volumetric loading rate, hydraulic retention time, specific gas yield, electrical and thermal efficiency. Students learn how to evaluate the efficiency of a biogas plant using key performance indicators.

The analysis of digestates is performed on both separated digestate and thin sludge after separation. A comparison with the digested sludge inoculum from the wastewater treatment plant illustrates the differences between various anaerobic systems.

Students begin with the substrate mixture calculation and learn how biogas plants can be designed to meet specific customer requirements.

Learning Objectives:

Students experience a biogas plant in real operation and are able to link theory with practice. They can record and interpret relevant operational data. They learn to evaluate the efficiency of a plant based on key performance indicators and can perform basic design calculations.

Day 7: Experimental setups for continuous trials, hydrolysis/acidogenesis, and anaerobic filter

Topic: Deepening the capabilities of the biogas laboratory and complex fermentation setups

Course Content:

Students gain insights into how complex, multi-stage processes can be simulated and the role substrate hydrolysis plays in this context. Continuous digestion experiments according to VDI 4630 form the basis for execution and evaluation.

In the laboratory, students initiate a continuously operated methane stage and a hydrolysis/acidogenesis experiment, which is conducted with pH control. This is the first stage of a two-stage biogas process, in which biomass is initially broken down into organic acids (particularly acetic acid).

Learning Objectives:

Students understand the advantages and disadvantages of different hydrolysis methods and can estimate the energy demand for various processes. They are able to implement the first stage of a two-stage process in the laboratory and comprehend the significance of pH value for process control.

Day 8: AI in Biogas Technology

Topic: AI-supported Process Optimization

Course Content:

The eighth day is dedicated to a forward-looking topic: AI-supported process optimization in biogas technology. The KI-Fermtec project of the Company is presented.

The three core functions of AI control are discussed in detail:

- Analysis and optimization of substrate mixtures: Students learn how AI algorithms can calculate the optimal composition of substrates based on the C:N:P:S ratio, trace elements, and economic parameters.
- Process monitoring through sensor technology: The importance of modern sensor technology is explained:
- NIR spectroscopy (near-infrared) for continuous characterization of substrate mixtures
- Online COD measurements to complement process monitoring
- Gas analysis to determine gas composition and quantity

- Forecasting and automated process control: Students learn how AI systems can make predictions about the future development of the biogas process and automatically initiate control measures.
- Carbon balancing as the basis for AI control is explored in depth. Students understand how the degree of biomass degradation is recorded in real time and used for process optimization.

In the laboratory, the hydrolysis experiment set up the previous day is evaluated. The resulting hydrolysate (rich in organic acids) is transferred to the methane stage, where it is converted into biogas. The students thus experience the second stage of the two-stage process. Furthermore, the analysis and feeding of the reactor systems are to be carried out.

Learning objectives:

The students understand the potential of artificial intelligence (AI) for optimizing biogas production. They learn about the functioning of an AI-supported control platform and comprehend the significance of modern sensor technology. They are able to implement the second stage of a two-stage process in the laboratory and explain the advantages compared to single-stage procedures.

Day 9: Material Utilization and Future Concepts

Topic: Alternative Utilization Pathways for Biomass

The ninth day broadens the horizon beyond mere biogas production and introduces material utilization pathways for biomass.

Biopolymers and Bioplastics: The students learn about the production of polyhydroxyalkanoates (PHA) from organic acids. The importance of the acetic acid fraction (GREEN OIL) as a raw material for biopolymers is explained. The vision that Ukraine could become the largest European manufacturer and exporter of bioplastics from biogenic residues is discussed.

Biochar and Activated Carbon: The use of the lignin-rich solid fraction from the TRIPPLE-S process for the production of biochar, activated carbon, or fuel pellets is presented.

International Research Approaches: Current research projects and international collaborations of the Company are presented, with particular emphasis on projects in Ethiopia and Ukraine.

Container-based biogas systems: The concept of decentralized, mobile biogas systems is introduced. Students learn about the advantages of container-based solutions for remote regions or temporary applications.

Learning objectives:

- Innovative methods for biomass conversion
- Eko grass gasifier: A technology for the thermal utilization of grass and other biomass
- The supervision of ongoing experiments continues, and the students begin the systematic evaluation of their experimental data.

Learning objectives:

Students learn about alternative utilization pathways for biomass and understand the concept of cascade use. They receive an overview of current research trends and international developments. They comprehend the concept of decentralized energy generation and can assess the economic significance of material utilization pathways.

Day 10: The BioScience LAB and course conclusion

Topic: Mobile research station and conclusion

Course content:

The final day is dedicated to the BioScience LAB, the mobile research and training concept of the Company.

The BioScience LAB as a Research Station: Students are introduced to the concept of the Cockpit Explorer, a mobile, fully equipped fermentation laboratory designed for research, training, and service. The functions as the initial stage of biogas plant planning as well as for the analysis and monitoring of existing plants are explained.

The Various Modules of the BioScience HUB are presented:

- BioScience FERMENTATION: Anaerobic fermentation processes
- BioScience HTC and VTC: Hydrothermal and vapothermal carbonization
- BioScience PYROLYSIS: Thermal decomposition of biomass
- BioScience CHEMICAL: Chemical conversion processes
- BioScience HYDROGEN: Hydrogen production from biomass

Training as a Substrate Manager: Students learn the requirements for professional substrate management, including occupational health and safety, fire protection, and employee planning and leadership.

The GREEN OIL Factory: The overall concept of the GREEN OIL Factory is presented once again in summary, from biomass through BLUE OIL and GREEN OIL to the various end products (biomethane, hydrogen, biopolymers, biofuel).

Experiment Evaluation and Report Preparation: Students systematically evaluate their experiments from the past two weeks and prepare a final report. The results are presented and discussed in a joint discussion session.

Final Discussion and Certificate Presentation: In a concluding session, students reflect on their learning experiences. Open questions are addressed, and students receive their participation certificates. They are encouraged to act as ambassadors for the technologies of the Company.

Learning Objectives:

Students understand the BioScience LAB as a versatile tool for research, development, and education. They are able to summarize, present, and scientifically evaluate the results of their laboratory experiments. They become informed ambassadors for the innovative technologies of the Company and can apply and disseminate the acquired knowledge in their home countries.

Summary of Learning Objectives

Upon completion of the two-week intensive course, participants are able to:

Theoretical Knowledge:

- Explain the biochemical fundamentals of anaerobic fermentation
- Characterize different types of biomass and assess their potential
- Compare the advantages and disadvantages of various biogas processes
- Apply the concept of carbon accounting
- Understand the significance of artificial intelligence for process optimization
- Container-based biogas plants
- Hydrothermal carbonization (HTC) process
- Material utilization of biomass (activated carbon, biochar, biopolymers, biorefinery, etc.)

Practical Skills:

- Conduct standardized experiments according to VDI 4630
- Independently performing basic laboratory analyses (FOS/TAC, pH, TS/oTS, COD)
- Conducting gas analysis and gas volume measurement
- Starting and monitoring continuous fermentation processes
- Operating and maintaining laboratory reactors
- Systematically recording and evaluating experimental data

Application competence:

- Assessing biogas plants based on operational parameters
- Calculating and optimizing substrate mixtures
- Designing biogas plants for specific requirements
- Identifying alternative utilization pathways for biomass
- Applying the BioScience LAB concept in various contexts

Multiplier function:

- Passing on the acquired knowledge to students and interested parties
- Acting as ambassadors for the technologies of the Company
- Initiating and supporting biogas projects in their home countries

Special Features of This Course

This course differs from conventional biogas courses through several distinctive features:

Integration of Innovative Methods: The course not only imparts standard knowledge but also introduces the innovative methods of the Company (TRIPPLE-S, GREEN OIL Factory, BioScience LAB).

Future Orientation: Topics such as AI-supported process optimization, material utilization of biomass, and decentralized energy systems prepare students for the future of biogas technology.

High Practical Component: From the third day onward, students work intensively in the laboratory and conduct experiments independently.

International Perspective: By incorporating international research projects and discussing global application possibilities, the course gains international relevance.

Holistic Approach: The course addresses not only biogas production but also alternative utilization pathways for biomass and the concept of cascade utilization.

Multiplier Training: Students are not only educated but explicitly prepared as multipliers and ambassadors for the technology.