Freie Universität Bozen
Libera Università di Bolzano
Università Liedia de Bulsan

Syllabus
Course description

Course title	Bioenergy
Course code	45535
Scientific sector	ING-IND/24 "Fundamentals of Chemical Engineering"
Degree	Master Energy Engineering
Semester	2
Year	2
Academic year	2025/2026
Credits	6
Modular	no

Total lecturing hours	60
Total lab and exercise hours	
Attendance	Recommended but not compulsory
Recommended preliminary knowledge	Capability to write mass and energy balances
Connections with other courses	In-depth knowledge of topics dealt with in previous courses. In this course we will make use of some of the concepts (thermodynamics, reaction kinetics, heat transfer, conversion technologies, combustion, heat exchangers) dealt with in previous courses, in particular in Power Production, CHP and District Heating Systems.
Course page	https://www.unibz.it/en/faculties/engineering/master-energy-engineering/

Specific educational objectives	The course focuses on Bioenergy and in particular on the exploitation of biomass and organic waste for energy recovery. The course encompasses thermochemical energy processes (combustion, gasification, pyrolysis, reforming, hydrothermal conversion), mechanical and chemical processes (oil extraction and trans-esterification), finally biochemical processes (fermentation and anaerobic digestion). Emphasis is given to thermochemical processes and anaerobic digestion. The course provides chemical engineering tools applied to the analysis of energy conversion processes involving biomass and organic waste. The course provides also the fundamentals of a software package designed for process modeling and simulation that is extensively utilized in chemical and energy industrial sectors. The student at the end of the course:

	• will be able to analyze the various technologies available to energetically valorize the various types of biomass and organic waste; • will be able to evaluate performances and limits of the same technologies in relation to the substrate to be treated; • will have clear concepts and design elements to address the design of a bioenergy plant.

Lecturer	Prof. Luca Fiori
Scientific sector of the lecturer	ING-IND/24
Teaching language	English
Office hours	The lecturer is available to meet students throughout the whole week, to be agreed through e-mail appointment.
Teaching assistant *(if any)*	-
Office hours	-
List of topics covered	**The (bio-)energy scenario. Biomass, Bio-Energy, Bio-Fuels and Bio-Refinery** • Biomass and bioenergy; Bioenergy production (World, Europe, Italy); Advantages and disadvantages; Carbon neutrality and negativity; Circular (bio)economy; Economic and environmental sustainability (EROI, LCA); Biofuels; Biorefineries **Biomass: Typologies, availability, properties and characterization** • Biomass typologies: lignocellulosic, starchy, sugary, oilseeds, OFMSW, sewage sludge, manure, algal biomass • Biomass: constituents at molecular level, at chemical level, energy properties. **Biomass conversion: Physical and chemical pretreatments** • Storage; Dewatering and drying; Size reduction; Densification; Transport; Separation and extraction • Steam explosion; Acid, alkaline and organosolv pre-treatment; Chemical pretreatment **Biomass conversion: Chemical and biochemical conversion - Synthesis of first-generation biofuels** • Bio-ethanol production (hydrolysis, fermentation, distillation, dehydration) • Biodiesel production (oil trans-esterification) • Anaerobic digestion and biogas production from organic waste and wastewater **Chemical engineering tools for analysis and design of energy processes** • Reaction stoichiometry • Reaction kinetics • Reaction thermodynamics • Reactors

	• Process analysis and design **Biomass conversion: Thermochemical conversion** • Pyrolysis, gasification, combustion: processes and plants • Hydrothermal processes: carbonization, liquefaction, gasification • Methane steam reforming • P&Id and safety issues **Treatment and valorization of products** • Gas cleaning and upgrading • Producer gas properties and uses • Bio-oil • Char and related materials **Process modeling and simulation with a commercial software** • Methane combustion for CHP: turbogas • Biomass gasification • Methane steam reforming **Biomass plants: case studies** • Design of a thermal plant fueled by wood chips P=70 kW. • Anaerobic digestion plant for organic waste P=999 kWe. • Bolzano WtE plant. • Copenhill WtE plant. • Gasifiers in Germany and Austria **Innovative processes for transport biofuels** • HVO, ethanol, LDO, HTL biocrude, FT-diesel, methanol, DME, H_2, CH_4.
Professional applications of the covered topics	The knowledge gained in the Bioenergy course will make the student a "process engineer" who can find employment in various industrial sectors, in particular but not only in relation to the energy conversion (mechanical, chemical, biochemical, thermochemical) of biomass and waste.
Teaching format	The course accounts for frontal lectures (50 hours), during which the lecturer will address both informative and formative topics. The informative activity will provide a comprehensive overview of the bio-energy sector. The training activity will be divided into a discussion of the theoretical topics and the development and solving of some "practical" problems, where the theory will be applied. The lecturer will use PowerPoint presentations, while the exercises will be held on the blackboard. The course also includes ten hours classes in a computer lab where basic knowledge will be provided for the use of a commercial process design and simulation software, and where the software will be used by students, along with the lecturer, to design simple thermochemical bio-energetic processes.

	Students will be provided in advance with the teaching material used during the classes (slides PP, lecture-notes, articles: classes are also intended to deeply and critically discuss the topics). The student, in his/her own personal work, must assimilate the concepts at the base of the training part and, if necessary, ask the lecturer (lesson time or other time) for additional explanations. During classes some exercises will be presented that the student will have to try to carry out autonomously, so that he/she can "self-evaluate" his/her level of learning. Finally, the student is invited to collaborate with his/her colleagues (in groups of 2-3 people) to draw up a bioenergy project to be developed in the simulation and design software taught. The design project should be agreed in advance with the lecturer who is available to help the student during the project development. The project will be concluded with a written report that will be discussed by the student groups in front of the lecturer.

Learning outcomes	**Intended Learning Outcomes (ILO)** **1. Knowledge and understanding:** The student will be aware from a technical point of view of energy plants where biomasses and organic waste are used. **2. Applying Knowledge and understanding:** The student will be capable of applying the acquired knowledge to design biomass energy plants and to evaluate their performances. **3. Making judgments:** The student will become capable of judging the different options available given the nature of the feedstock available (kind of biomass, kind of organic waste) and the technological opportunities to valorize it as bioenergy. **4. Communication skills:** The student will be capable of efficiently communicating concerning bio-energy options, processes and plants. **5. Learning skills** The student will be taught that significant bioenergy process advancements are in progress, and that he/she should keep him/herself updated on the last technological outcomes that face the bio-energy market.

Assessment	The assessment of the knowledge gained on the course and the ability to apply such knowledge - as described in the "Learning Outcomes" section - is conducted in two steps: • a presentation with discussion, in the lecturer's office, that will be based on the written report by the student (or better by the group of students) concerning the project of a thermo-energy process – project developed by the student(s) using the commercial software taught. • an oral exam that will cover the various topics addressed in the course and where the student can also be asked to solve a "simple" bio-energy exercise. The final exam mark will take into account both the project work presentation and the oral exam.
Assessment language	English
Evaluation criteria and criteria for awarding marks	Capability to address practical and theoretical issues related to bio-energy processes and plants. Capability to solve simple and complex bio-energy problems. Capability to design bio-energy processes by a commercial design and simulation software.

Formative assessment

Form	Length / duration	ILOs assessed
In class (and info-lab) exercises	20 x 60 minutes	2

Summative assessment

Form	%	Length / duration	ILOs assessed
Project work presentation	30	Presentation and discussion in group (about 45 minutes)	2,3,4
Oral exam	70	3-4 open questions	1,2,3,4,5

Required readings	Lecture notes and other material provided by the lecturer
Supplementary readings	Main reference books: • Biomass for renewable energy, fuels, and chemicals. D.L. Klass, Academic Press, http://www.sciencedirect.com/science/book/9780124109506 AVAILABLE ON-LINE FOR FREE

	• Biogas – Green Energy – Process, Design, Energy Supply, Environment, by Peter Jacob Jørgensen, PlanEnergi, https://www.lemvigbiogas.com/BiogasPJJuk.pdf AVAILABLE ON-LINE FOR FREE • Sistemi a biomasse: progettazione e valutazione economica. E. Bocci, A. Caffarelli, M. Villarini, A. D'Amato, Maggioli Editore, http://www.maggiolieditore.it/9788838759697-sistemi-a-biomasse-progettazione-e-valutazione-economica.html Other reference books: • Biogas Handbook, by Teodorita Al Seadi, Dominik Rutz, Heinz Prassl, Michael Köttner, Tobias Finsterwalder, Silke Volk, Rainer Janssen, https://lemvigbiogas.com/BiogasHandbook.pdf AVAILABLE ON-LINE FOR FREE