Syllabus

Course Description

Course Title	Bioenergy
Course Code	45535
Course Title Additional	
Scientific-Disciplinary Sector	ICHI-01/B
Language	English
Degree Course	Master in Energy Engineering
Other Degree Courses (Loaned)	
Lecturers	Dr. Luca Fiori, Luca.Fiori@unibz.it https://www.unibz.it/en/faculties/engineering/academic-staff/person/33953
Teaching Assistant	
Semester	Second semester
Course Year/s	2
CP	6
Teaching Hours	60
Lab Hours	0
Individual Study Hours	90
Planned Office Hours	18
Contents Summary	The course focuses on Bio-Energy: the exploitation of biomass for energy. The course addresses the different types of biomass: virgin (woody biomass, agricultural biomass, algae), residual (agro-industrial, zootechnical), and urban waste: OFMSW and sewage sludge. The course addresses thermochemical energy processes (combustion, gasification, pyrolysis, reforming, hydrothermal conversion), mechanical and chemical processes (oil extraction and trans-esterification for biodiesel), biochemical processes (fermentation for bioethanol; anaerobic digestion for biogas and upgrading to biomethane).

	The course provides chemical and process engineering tools applied to the design of energy conversion processes and plants based on biomass and organic waste. The course also provides the skills to use open source process simulation and modeling software (DWSIM), industrial reference software for the chemical and energy engineering sectors and a valid tool for process design and optimization. By the end of the course, students will: • be able to evaluate the various technologies available for energy recovery from various types of biomass and organic waste; • be able to assess the performance and limitations of these technologies with respect to the substrate to handle and the various attainable energy products (heat, electricity, biofuels, energy carriers). • have clear concepts and design elements for a bioenergy plant (digester for biogas and biomethane, gasifier, combustor-boiler, reformer for hydrogen production).
Course Topics	The (bio-)energy scenario. Biomass, Bio-Energy, Bio-Fuels and Bio-Refinery • Biomass and bioenergy; Bioenergy production (World, Europe, Italy); Strengths and weaknesses; 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 • Bio-ethanol production (hydrolysis, fermentation, distillation,

	dehydration) • Biodiesel production (oil trans-esterification) • Anaerobic digestion and biogas production from organic waste and sewage sludge 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 for H2 production • 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 open-source software DWSIM • Methane combustion for CHP: turbogas • Biomass gasification • Methane steam reforming for H2 production Biomass plants: case studies • Design of a thermal plant fueled by wood chips (P=70 kW) • Anaerobic digestion plant for organic waste (P=1 Mwe) • 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, H2,

	CH4
Keywords	Biomass, Organic waste, Biofuels, Process modeling-simulation-design, Chemical Engineering
Recommended Prerequisites	Capability to perform mass and energy balances.
Propaedeutic 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.
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 biomass and bio-energy sector. The formative-training activity consists in the explanation of the theoretical topics and in the development and solving of some "practical cases", where the theory will be applied. The lecturer will use PowerPoint presentations, while the exercises will be held on the blackboard. The course also accounts for 10 hours in the computer lab where students will be taught how to use the open-source process simulation and modeling software DWSIM. Students will use this software, along with the lecturer, to design thermochemical bioenergy 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 deep and critically discuss the topics. The student, in their own personal work, must assimilate the concepts at the base of the training part and, if necessary, ask the lecturer (lecture time or other time) for additional explanations. During classes some exercises will be proposed that the student will have to try to carry out autonomously, so that they can "self-evaluate" their level of learning. Finally, the student will have to draw up a bio-energy project (to be developed by means of modeling and simulation software) within a small working group (consisting of 2-3 students). 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.

Mandatory Attendance	Recommended but not compulsory.
Specific Educational Objectives and 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.
Specific Educational Objectives and Learning Outcomes (additional info.)	
Assessment	The assessment of the knowledge acquired during the course and the ability to apply this knowledge - as described in the section "Educational objectives and learning outcomes" - is carried out in two stages: • a discussion that will be based on a written report produced by the student (or better by the group of students - max 3 students) regarding the project of an energy process developed by using the modeling and simulation software. Downstream of the discussion, the lecturer will assign the student a mark which will have a weight of 30% on the final mark. Such a discussion must be held before the oral exam (point below).

	• an oral exam that will cover the different topics addressed in the course. The oral exam mark will have a weight of 70% on the final mark. Discussion of the project and oral exam will take place respectively in the lecturer's study and in a classroom. The written report relating to the energy process design must be sent to the lecturer by mail well before the students take the oral exam. The lecturer will read the report and possibly request a revision by the students. The date of discussion of the design report will then be set by email; all students involved in the project must participate in such a discussion. This discussion must be made before the oral exam, which can be held on any of the dates scheduled for the exam (the mark related to the written design report and its discussion does not expire). The oral exam will consist of open questions and setting/conducting exercises for which the student will have to write equations and make diagrams. - Formative assessment: In class (and info-lab) exercises: 20x60 minutes; ILOs assessed: 2. - Summative assessment: 30% project work presentation: Presentation and discussion in group (about 45 minutes); ILOs assessed: 2, 3, 4; 70% oral exam: 3-4 open questions; ILOs assessed: 1,2,3,4,5.
Evaluation Criteria	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 open-source modeling and simulation software.
Required Readings	Lecture notes and other material provided by the lecturer. · Advancing bioenergy for a green future - Editorial by Ischia, Marchelli & Fiori, https://doi.org/10.31025/2611-4135/2023.18278 AVAILABLE ON-LINE FOR FREE · 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
Supplementary Readings	Other books of interest: · 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 · W la CO2, by Gianfranco Pacchioni, Il Mulino https://www.scienzainrete.it/articolo/w-co2-lultimo-libro-di-gianfranco-pacchioni/jolanda-pisano/2021-08-25
Further Information	
Sustainable Development Goals (SDGs)	Affordable and clean energy, Climate action, Responsible consumption and production