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
Degree	Master Energy Engineering
Semester	2
Year	2
Academic year	2020/2021
Credits	6
Modular	no

Total lecturing hours	50
Total lab hours	10
Total exercise hours	
Attendance	Reccomended but not compulsory
Prerequisites	Capability to write mass and energy balances
Course page	

Specific educational objectives	The course focuses on Bio-Energy 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 ASPEN PLUS® - 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	Luca Fiori
Scientific sector of the lecturer	ING-IND/24
Teaching language	English
Office hours	The lecturer is available to meet students along the whole week, to be agreed through e-mail appointment.
Teaching assistant *(if any)*	
Office hours	
List of topics covered	**Biomass, Bio-Energy and Bio-Refinery** • Basic concepts of circular economy based on organics. **Biomass: Properties and types** • Biomass: constituents at molecular level, at chemical level, energy properties. • Biomass typologies: lignocellulosic, starchy, sugary, oilseeds, OFMSW, sewage sludge, manure. • Biofuels: liquid (biodiesel, bioethanol), gaseous (syngas, biogas), solid (charcoal and biochar). **Biomass conversion: Physical conversion** • Dewatering, drying, size reduction, steam explosion, densification, pelleting, chipping, oil extraction. **Biomass conversion: Chemical conversion** • Oil trans-esterification (biodiesel production). • Hydrolysis. **Biomass conversion: Biochemical conversion** • Anaerobic digestion (biogas production from organic waste and wastewater). • Fermentation (bioethanol production) **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** • Biomass storage and feeding systems. • Combustion plants for heat generation: wood and pellet burning stoves; wood, pellet and wood chips boilers; plant schemes for heat generation; control, protection and safety systems. • Gasification plants. • Pyrolysis plants. • Innovative bioenergy plants: biomass to synthetic natural gas; biomass to liquid biofuels through Fisher-Tropsch; absorption enhanced reforming. • Hydrothermal processes: carbonization, liquefaction, gasification. **Algal biofuels** • Growth/harvest rates, transesterification. **Process modeling and simulation with the**

	commercial software ASPEN PLUS® • Methane combustion and methane steam reforming. • Gasification of biomass. • Thermochemical processes coupled to gas turbine, Rankine cycles…) **Project of biomass plants** • Design of a thermal plant fueled by wood chips P=70 kW. • Cogeneration plant (ICE) fueled by vegetable oil P=1 MWe. • Anaerobic digestion plant for organic waste P=999 kWe.
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 solution 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 ASPEN PLUS® simulation and modeling software, and where ASPEN PLUS® 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 deep 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 Aspen Plus. The design project should be agreed in advance with the lecturer who is available for helping 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	**Knowledge and understanding:** The student will be aware from a technical point of view of energy plants where biomasses and organic wastes are used. **Applying Knowledge and understanding:** The student will be capable to apply the acquired knowledge to design biomass energy plants and to evaluate their performances. **Making judgments:** The student will became capable to judge 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. **Communication skills:** The student will be capable to efficiently communicate concerning bio-energy options, processes and plants. **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 in the course and the ability to apply such knowledge - as described in the "Learning Outcomes" section - is conducted in two steps: • a 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 Aspen Plus project of a thermo-energy process. Following the discussion, the lecturer will give the student a grade in the range 2-4/30. • an oral exam that will cover the various topics addressed in the course and where the student will also be asked to solve a "simple" bio-energy exercise. Drawing up the Aspen Plus project of a thermo-energy process is strongly recommended but still optional. The final exam mark will be the sum of the mark of the oral examination and the mark of the project in Aspen Plus.
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 ASPEN PLUS®.

Required readings	Lecture notes
Supplementary readings	Main reference books: Biomass for renewable energy, fuels, and chemicals. D.L. Klass, Academic Press,

	http://www.sciencedirect.com/science/book/9780124109506 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: Advanced Biofuels and Bioproducts, J. W. Lee, http://www.springer.com/cn/book/9781461433477 Algae for Biofuels and Energy, M.A. Borowitzka, N.R. Moheimani, http://www.springer.com/br/book/9789400754782 Application of Hydrothermal Reactions to Biomass Conversion, F. Jin, http://www.springer.com/cn/book/9783642544576 Biogas Energy, T. Abbasi, S.M., Tauseef, S.A. Abbasi, http://www.springer.com/us/book/9781461410393 BioH_2 & BioCH_4 through Anaerobic Digestion, B. Ruggeri, T. Tommasi, S. Sanfilippo, http://www.springer.com/us/book/9781447164302 Biomass Conversion, C. Baskar, S. Baskar, R.S. Dhillon, https://link.springer.com/book/10.1007%2F978-3-642-28418-2 Recycling of Solid Waste for Biofuels and Bio-chemicals, O.P. Karthikeyan, K. Heimann, S.S. Muthu, http://www.springer.com/cn/book/9789811001482