Course guide
820742 - BBC - Biogas and Biofuels

Last modified: 26/06/2024

Unit in charge: Barcelona School of Industrial Engineering
Teaching unit: 751 - DECA - Department of Civil and Environmental Engineering.

Degree: MASTER'S DEGREE IN ENERGY ENGINEERING (Syllabus 2013). (Optional subject).
MASTER'S DEGREE IN ENVIRONMENTAL ENGINEERING (Syllabus 2014). (Optional subject).
MASTER'S DEGREE IN INDUSTRIAL ENGINEERING (Syllabus 2014). (Optional subject).
MASTER'S DEGREE IN ENERGY ENGINEERING (Syllabus 2022). (Optional subject).

Academic year: 2024 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: Ferrer Martí, Ivet

Others: Passos, Fabiana

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEMT-1. Understand, describe and analyse, in a clear and comprehensive manner, the entire energy conversion chain, from its status as an energy source to its use as an energy service. They will also be able to identify, describe and analyse the situation and characteristics of the various energy resources and end uses of energy, in their economic, social and environmental dimensions, and to make value judgments.
CEMT-4. Efficiently collect data on renewable energy resources and their statistical treatment and apply knowledge and endpoint criteria in the design and evaluation of technology solutions for using renewable energy resources, for both isolated systems and those connected to networks. They will also be able to recognise and evaluate the newest technological applications in the use of renewable energy resources.
CEMT-6. Employ technical and economic criteria to select the most appropriate electrical equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technology applications in the field of production, transport, distribution, storage and use of electric energy.
CEMT-7. Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.

TEACHING METHODOLOGY

The teaching methodologies used are as follows:
- Lectures and conferences: contents exposed by lecturers or guest speakers.
- Practical sessions: resolution of exercises, debates and group dynamics with the lecturer and other students in the classroom; classroom presentation of an activity individually or in small groups.
- Laboratory / Workshop: field trip.
- Theoretical / practical supervised work: classroom activity, carried out individually or in small groups, with the advice and supervision of the teacher.
- Homework assignment of reduced extension: to carry out homework of reduced extension, individually or in groups.
- Homework assignment of broad extension (PA): design, planning and implementation of a project or homework assignment of broad extension to be performed by a group of students, and writing of a report that should include the approach followed, the main results obtained and the conclusions reached.
- Evaluation activities.

The training activities used are as follows:
Face to face activities
- Lectures and conferences: learning based on understanding and synthesizing the knowledge presented by the teacher or by invited speakers.
- Participatory sessions: learning based on participating in the collective resolution of exercises, as well as in discussions and group dynamics with the lecturer and other students in the classroom.
- Presentations: learning based on the presentation of an activity in the classroom, individually or in small groups.
- Laboratory / Workshop: field trip.
- Theoretical-practical supervised work: learning based on performing an activity in the classroom with the advice of the teacher.

Study activities
- Homework assignment of reduced extension: learning based on applying the gained knowledge and presenting results, individually or in small groups.
- Homework assignment of broad extension: learning based on applying and extending knowledge gained in class, individually or in group.
- Self-study: learning based on studying or extending the contents of the class material, individually or in groups, understanding, assimilating, analyzing and synthesizing concepts.

LEARNING OBJECTIVES OF THE SUBJECT

Objective: To build a solid foundation of knowledge and skills to face the design of biofuels production facilities.
At the end of the course, the student:
- Understands the role of bioenergy in the global and regional energy system; is aware of economic, social and environmental impacts; understands the impact of associated technologies in a local and global context.
- Knows relevant organizations and major projects at regional and international scale; along with the main information sources and regulations.
- Has criteria for the analysis and knowledge to carry out a basic engineering project on the production of biofuels.
- Is able to transfer knowldedge related to the implementation of technologies for the production of biofuels by developing innovative ideas.

STUDY LOAD

Type	Hours	Percentage
Hours large group	30,0	23.08
Self study	85,0	65.38
Hours small group	15,0	11.54

Total learning time: 130 h

CONTENTS

1. General context and introduction to biological processes

Description:
1.1. Introduction
Classification of biofuels, liquid and gaseous
Production processes
Raw materials and products. The concept of biorefinery
Current productions and future trends
Environmental, economic and regulatory issues
1.2. Introduction to biological processes of transformation
Bioreactor concepts
Kinetics of microbial growth
Enzymatic kinetics
Bioenergetics of biological reactions. Transformation of the substrate in biomass
Applications of batch, CSTR and plug flow reactors
Concepts of biofilm kinetics and fixed biomass reactors

Specific objectives:
To establish the basis of information on the context of the production of liquid and gaseous biofuels, and the basis of knowledge on biological processes for the transformation of organic substrates into biofuels.

Related activities:
1. Lectures and conferences (CTC)
2. Practical classes (CP) and project, activity or reduced-scope work (PR)
3. Tutoring theoretical-practical studies (TD), and wide-scope project (PA)

Full-or-part-time: 34h
Theory classes: 4h
Laboratory classes: 4h
Guided activities: 4h
Self study : 22h

2. Gaseous biofuels: biogas and biohydrogen

Description:
2.1. Anaerobic digestion. Microbiology and kinetics
- Phases of anaerobic digestion
- Disintegration and hydrolysis; Acidogenesis; Acetogenesis; Methanogenesis
- Syntrophic relationships between species
- Relevant chemical equilibria
- IWA-ADM1 Model (Anaerobic Digestion Model No. 1)

2.2. Anaerobic digestion. Environmental and operational conditions
- Temperature
- pH and alkalinity
- Nutrients requirement
- Toxics and inhibitors
- Solid and hydraulic retention times
- Organic loading rate
- Granulation of anaeroobic biomass

2.3. Bioreactors for the production of biogas and scope
- Batch Reactor
- Continuous Stirred Tank Reactor (CSTR)
- CSTR reactors with recirculation of biomass (anaerobic contact)
- Fixed biomass reactors: anaerobic filters and fixed bed
- Retaining granular biomass reactors: UASB and EGSB
- Hybrid reactors hybrid and two stage processes

2.4. Application to the production of biogas from waste and solid substrates
Cattle manure
Municipal organic waste
Sewage sludge
Industrial organic waste
Energy crops
Codigestion
Environmental, energy, economic and regulatory issues
2.5. Application to the production of biogas from wastewater
Wastewaters with high organic content
Applications of anaerobic contact, fixed bed, UASB and EGSB reactors
Environmental, energy, economic and regulatory issues
2.6. Pre-treatment and post-treatment to anaerobic digestion
Pre-treatment to improve disintegration and hydrolysis
Post-treatment to improve management of digested effluents
2.7. Treatment and use of biogas
Composition of biogas
Removal of H2S, water and particles
Removal of CO2 and production of biomethane
Thermal, electrical and automotive uses. Injection to natural gas network
Regulations related to the quality and use of biogas
2.8. Production of biohydrogen
Production by dark fermentation
Production by photo-fermentation
Analysis of the stoichiometry in reactions
Bioreactors used

Specific objectives:
To stablish the basis on the scientific and technological knowledge of digestion and fermentation processes for the production and use of biogas, biomethane and biohydrogen from organic substrates of different origin.

Related activities:
1. Lectures and conferences (CTC)
2. Practical classes (CP), and project, activity or reduced-scope work (PR)
3. Tutoring theoretical-practical studies (TD) and wide-scope project (PA)

Full-or-part-time: 65h
Theory classes: 8h
Laboratory classes: 8h
Guided activities: 7h
Self study : 42h

3. Liquid biofuels

Description:

3.1. Production of bioethanol
- Raw materials and pretreatment processes
- Enzymatic hydrolysis of cellulose and hemicellulose
- Fermentation of monosaccharides
- Stages according to the biological process strategy
- Recovery of bioethanol
- Uses of bioethanol. Production of ETBE
- Regulations associated with its use as biofuel

3.2. Production of other bioalcohols
- Production of butanol. ABE fermentation (acetone-butanol-ethanol)
- Stoichiometry of the process reaction
- Environmental and operational conditions

3.3. Production of biodiesel
- The transesterification reaction
- Raw materials and pretreatment processes
- Environmental conditions and operational process
- Separation and purification stages
- Qualities of biodiesel and associated regulations

3.4. Other processes for the production of liquid biofuels
- Refined oils as fuel
- Hydrogenation of unsaturated lipids and bioquerosene production
- The Fischer-Tropsch process for the production of hydrocarbons from syngas

Specific objectives:

To build the base of the scientific and technological knowledge of the biological and chemical processes for the production of bioalcohols, biodiesel and other liquid biofuels from lignocellulosic biomass, oils and fats.

Related activities:

1. Lectures and conferences (CTC)
2. Practical classes (CP) and project, activity or reduced-scope work (PR)
3. Tutoring theoretical-practical studies (TD) and wide-scope project (PA)

Full-or-part-time: 26h
Theory classes: 3h
Laboratory classes: 3h
Guided activities: 4h
Self study : 16h

ACTIVITIES

1. Lectures and conferences (CTC)

Description:
Exposure of the theoretical contents, progressing from basic principles to description of applicable technologies.

Specific objectives:
To synthesize knowledge and to organize the study, so that the students can prioritize the study depth level in each subject.

Material:
MS-Powerpoint presentations and other specific documentation that will be given to the student.

Delivery:
For this activity, the deliverable will consist on an exam, including conceptual questions and links between the studied subjects.

Full-or-part-time: 45h
Theory classes: 15h
Self study: 30h

2. Practical classes (CP) and project, activity or reduced-scope work (PR)

Description:
Resolution of exercises and problems in class (CP).

Specific objectives:
To achieve skills to solve problems dealing with biological reactions and stoichiometries, and on the dimensioning of facilities for each process and technology, with a limited scope.

Material:
Exercises and problems

Delivery:

Full-or-part-time: 45h
Laboratory classes: 15h
Self study: 30h

3. Tutoring theoretical-practical studies (TD) and wide-scope project (PA)

Description:
Dimensioning of a complex facility fed with several raw feedstocks which may combine several processes to produce gas and/or liquid biofuels. The students will be distributed in various subgroups, each one working on a given process, or in a given combination of raw feedstocks. A subgroup may coordinate the different studies and will perform the global mass and energy balance.

Specific objectives:
To address a practical project that integrates knowledge provided to the students during the course by connecting different concepts and complexity levels, thus promoting an atmosphere of creation of new solutions resulting from teamwork.

Material:
Statement of the project to be carried out, the extent of which will depend on the total number of students enrolled.

Delivery:
- Regular presentations by each subgroup about the progress of the work.
- Delivery of a final report that integrates the work of all subgroups.

Full-or-part-time: 30h
Self study: 15h
Guided activities: 15h

4. Field trip

Description:
Field trip to a biomethanation plant

Specific objectives:
To describe a biomethanation plant

Full-or-part-time: 5h
Laboratory classes: 5h

GRADING SYSTEM

Written test of knowledge (PE): 50%
Assignments done individually or in groups (TR): 50%

EXAMINATION RULES.

The examination will be held individually and consists of two parts: theory and exercises. During the exam, it will not be allowed the accession to the internet nor the use of mobile phones.
TR: The evaluation will be done based on two kinds of activities: oral presentation of an assignement; and a report on a biogas project. Both activities will be conducted in groups of no more than three people.

BIBLIOGRAPHY

Basic:
- Khanal, S.K.; Surampalli, R.Y.; Zhang, T.C.; Lamsal, B.P.; Tyagi, R.D.; Kao, C.M. Bioenergy and biofuel from biowastes and biomass [on line]. Reston, Virginia: American Society of Civil Engineers, 2010 [Consultation: 25/10/2024]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=3115296. ISBN 9780784473306.
- Mousdale, D.M. Biofuels : biotechnology, chemistry, and sustainable development [on line]. Boca Raton, FL: CRC Press, cop. 2008 [Consultation: 25/10/2024]. Available on: https://www-taylorfrancis-com.recursos.biblioteca.upc.edu/books/mono/10.1201/9781420051254/biofuels-david-mousdale. ISBN 9781420051247.
- Solera del Río, R.; Álvarez, C.J.; Aymerich, E.; Bedmar, E.J.; Carballa, M.; Castrillón, L.; Flotats, X.; Font, X.; López, M.J.; Marañón, E.; Prenafeta, F.; Tortosa, G.; Vicent, T.. Aspectos biológicos de la digestión anaeróbica. Madrid: Mundi-Prensa, 2014. ISBN 9788484767008.
- Flotats, X.; Bonmatí, A.; Fernández, B.; Sales, D.; Aymerich, E.; Irizar, I.; Palatsi, J.; Romero, L.I.; Pérez, M.; Vicent, T.; Font, X.. Ingeniería y Aspectos Técnicos de la Digestión Anaeròbica. II.4. Madrid: Ediciones Mundi-Prensa, 2016. ISBN 9788484766292.

Complementary:
- Mata-Alvarez, J. (ed.). Biomethanization of the organic fraction of municipal solid wastes [on line]. London, UK: IWA, 2003 [Consultation: 14/11/2024]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=3120718. ISBN 1900222140.
- Rittmann, B.E.; McCarty, P.L.. Environmental Biotechnology : Principles and Applications. New York, USA: McGraw-Hill, 2001. ISBN 9780071181846.
- Batstone, D. J. [i 8 més]. Anaerobic digestion model no.1 [on line]. London, UK: IWA Publishing, 2002 [Consultation: 01/10/2024]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=3120725. ISBN 1900222787.

RESOURCES

Audiovisual material:
- Ordinador, projector i panatalla. MS-PowerPoint presentations

Computer material:
- Programa MATLAB. MATLAB as software for performing numerical simulations of the anaerobic digestion process and codigestion