

820742 - BBC - Biogas and Biofuels

Coordinating unit:	240 - ETSEIB - Barcelona School of Industrial Engineering
Teaching unit:	751 - DECA - Department of Civil and Environmental Engineering
Academic year:	2019
Degree:	MASTER'S DEGREE IN ENERGY ENGINEERING (Syllabus 2013). (Teaching unit Optional) MASTER'S DEGREE IN ENVIRONMENTAL ENGINEERING (Syllabus 2014). (Teaching unit Optional) MASTER'S DEGREE IN ENVIRONMENTAL ENGINEERING (Syllabus 2009). (Teaching unit Optional) MASTER'S DEGREE IN ENERGY ENGINEERING (Syllabus 2013). (Teaching unit Optional)
ECTS credits:	5
Teaching languages:	English

Teaching staff

Coordinator:	Ferrer Martí, Ivet
Others:	Flotats Ripoll, Xavier García Galán, Maria Jesús

Opening hours

Timetable:	To be published in the intranet
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Prior skills

- Stoichiometry of chemical reactions
- Mass balance. Continuity equation
- Fundamentals of thermodynamics in chemical reactions

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.

820742 - BBC - Biogas and Biofuels

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 sizing and design of production facilities of liquid and gaseous biofuels.

At the end of the course, the student:

- Understands the role of bioenergy in the context of the global and regional energy system; Understands economic, social and environmental connotations; Understands the impact of associated technologies in a local and global context.
- Meets relevant organizations and major projects at regional and international scale; Meets main information sources and regulations related to the biogas plants as well as with production and quality of other biofuels.
- Has criteria for the analysis and knowledge to carry out the basic engineering of a project related to the production of gaseous and liquid biofuels as well as about the management of the corresponding facilities.
- Is able to transfer knowledge related to the implementation of technologies for the production of biofuels by developing innovative ideas.



820742 - BBC - Biogas and Biofuels

Study load

Total learning time: 125h	Hours medium group:	30h	24.00%
	Hours small group:	0h	0.00%
	Guided activities:	10h	8.00%
	Self study:	85h	68.00%

820742 - BBC - Biogas and Biofuels

Content

1. General context and introduction to biological processes

Learning time: 34h

Theory classes: 4h
Laboratory classes: 4h
Guided activities: 4h
Self study : 22h

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

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)

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.

820742 - BBC - Biogas and Biofuels

2. Gaseous biofuels: biogas and biohydrogen	Learning time: 65h Theory classes: 8h Laboratory classes: 8h Guided activities: 7h Self study : 42h
Description:	

820742 - BBC - Biogas and Biofuels

- 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 anaerobic 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

Related activities:

820742 - BBC - Biogas and Biofuels

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)

Specific objectives:

To establish 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.

820742 - BBC - Biogas and Biofuels

<p>3. Liquid biofuels</p>	<p>Learning time: 26h Theory classes: 3h Laboratory classes: 3h Guided activities: 4h Self study : 16h</p>
<p>Description:</p> <ul style="list-style-type: none"> 3.1. Production of bioethanol <ul style="list-style-type: none"> 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 <ul style="list-style-type: none"> Production of butanol. ABE fermentation (acetone-butanol-ethanol) Stoichiometry of the process reaction Environmental and operational conditions 3.3. Production of biodiesel <ul style="list-style-type: none"> 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 <ul style="list-style-type: none"> Refined oils as fuel Hydrogenation of unsaturated lipids and bioquerosene production The Fischer-Tropsch process for the production of hydrocarbons from syngas <p>Related activities:</p> <ol style="list-style-type: none"> 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) <p>Specific objectives:</p> <p>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.</p>	

820742 - BBC - Biogas and Biofuels

Planning of activities

<p>1. Lectures and conferences (CTC)</p>	<p>Hours: 45h Theory classes: 15h Self study: 30h</p>
<p>Description: Exposure of the theoretical contents, progressing from basic principles to description of applicable technologies.</p> <p>Support materials: MS-Powerpoint presentations and other specific documentation that will be given to the student.</p> <p>Descriptions of the assignments due and their relation to the assessment: For this activity, the deliverable will consist on an exam, including conceptual questions and links between the studied subjects.</p> <p>Specific objectives: To synthesize knowledge and to organize the study, so that the students can prioritize the study depth level in each subject.</p>	
<p>2. Practical classes (CP) and project, activity or reduced-scope work (PR)</p>	<p>Hours: 45h Laboratory classes: 15h Self study: 30h</p>
<p>Description: Resolution of exercises and problems in class (CP). Resolution by the student of a collection of problems and exercises for each topic (PR), which must be delivered within the established deadlines in class.</p> <p>Support materials: Exercises and problems solved. Collection of exercise and problem statements to be solved by the students.</p> <p>Descriptions of the assignments due and their relation to the assessment: Delivery of a collection of solved exercises and problems, to be evaluated.</p> <p>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.</p>	
<p>3. Tutoring theoretical-practical studies (TD) and wide-scope project (PA)</p>	<p>Hours: 30h Guided activities: 15h Self study: 15h</p>
<p>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.</p>	

820742 - BBC - Biogas and Biofuels

Support materials:

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

Descriptions of the assignments due and their relation to the assessment:

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

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.

4. Field trip

Hours: 5h

Laboratory classes: 5h

Description:

Field trip to a biomethanation plant

Specific objectives:

To describe a biomethanation plant

Qualification system

Written test of knowledge (PE): 55%

Assignments done individually or in groups (TR): 45%

Regulations for carrying out activities

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: a compilation of exercises to be solved and delivered before the exam; and a report on the proposed dimensioning of a complex installation, similarly to a biorefinery. Both activities will be conducted in groups of no more than three people.

820742 - BBC - Biogas and Biofuels

Bibliography

Basic:

Khanal, S.K.; Surampalli, R.Y.; Zhang, T.C.; Lamsal, B.P.; Tyagi, R.D.; Kao, C.M.. Bioenergy and Biofuels from Biowastes and Biomass. Virginia, USA: American Society of Civil Engineers, 2010. ISBN 9780784410899.

Mousdale, D.M.. Biofuels : Biotechnology, Chemistry, and Sustainable Development. Boca Raton, USA: CRC Press, 2008. ISBN 9781420051247.

Solera, 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 Anaerobia II.2. Madrid: Ediciones 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 Anaeróbica. II.4. Madrid: Ediciones Mundi-Prensa, 2016. ISBN 9788484766292.

Complementary:

Mata-Alvarez, J.. Biomethanization of the Organic Fraction of Municipal Solid Wastes. London, UK: IWA Publishing, 2002. ISBN 9781900222143.

Rittmann, B.E.; McCarty, P.L.. Environmental Biotechnology : Principles and Applications. New York, USA: McGraw-Hill, 2001. ISBN 9780071181846.

Batstone, D.J.; Keller, J.; Angelidaki, I.; Kalyuzhnyi, S.V.; Pavlostathis, S.G.; Rozzi, A.; Sanders, W.T.M.; Siegrist, H.; Vavilin, V.A.. Anaerobic Digestion Model No.1. London, UK: IWA Publishing, 2002. ISBN 9781900222785.

Others 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