### 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:** 2018  
**Degree:**  
- MASTER’S DEGREE IN ENERGY ENGINEERING (Syllabus 2013). (Teaching unit Optional)  
- MASTER’S DEGREE IN ENVIRONMENTAL ENGINEERING (Syllabus 2009). (Teaching unit Optional)  
- MASTER’S DEGREE IN ENVIRONMENTAL ENGINEERING (Syllabus 2014). (Teaching unit Optional)  
- MASTER’S DEGREE IN ENERGY ENGINEERING (Syllabus 2013). (Teaching unit Optional)  
**ECTS credits:** 5  
**Teaching languages:** Spanish, English

#### Teaching staff

**Coordinator:** Magrí Aloy, Albert  
**Others:**  
- Magrí Aloy, Albert  
- Cerrillo Moreno, Miriam  
- Ferrer Martí, Ivet

#### Opening hours

**Timetable:** To be published in the intranet

#### 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.
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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.

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: completion of designs, measurements, verifications, etc.; and presentation of the results orally or written, individually or in small groups.
- 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: learning based on the understanding of the operation, specifications and documentation of technical equipment; design, measurements, verifications, etc.; and presentation of the results orally or written, individually or in small groups.
- 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
### Study load

<table>
<thead>
<tr>
<th>Total learning time: 125h</th>
<th>Hours large group: 0h 0.00%</th>
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<tbody>
<tr>
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<td>Hours medium group: 30h 24.00%</td>
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<td>Hours small group: 0h 0.00%</td>
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<td></td>
<td>Guided activities: 10h 8.00%</td>
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<td>Self study: 85h 68.00%</td>
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## Content

<table>
<thead>
<tr>
<th>Learning time: 34h</th>
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<tbody>
<tr>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td>Laboratory classes: 4h</td>
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<tr>
<td>Guided activities: 4h</td>
</tr>
<tr>
<td>Self study : 22h</td>
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</table>

### 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

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.
## 2. Gaseous biofuels: biogas and biohydrogen

<table>
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<th>Description:</th>
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**Learning time:** 65h  
- Theory classes: 8h  
- Laboratory classes: 8h  
- Guided activities: 7h  
- Self study: 42h
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:
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.
# 3. Liquid biofuels

**Learning time:** 26h  
Theory classes: 3h  
Laboratory classes: 3h  
Guided activities: 4h  
Self study : 16h

<table>
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<tr>
<th>Description</th>
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| **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 |

**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 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.
### Planning of activities

| 1. Lectures and conferences (CTC) | Hours: 45h  
Theory classes: 15h  
Self study: 30h |
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<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Exposure of the theoretical contents, progressing from basic principles to description of applicable technologies.</td>
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<tr>
<td><strong>Support materials:</strong></td>
<td>MS-Powerpoint presentations and other specific documentation that will be given to the student.</td>
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<tr>
<td><strong>Descriptions of the assignments due and their relation to the assessment:</strong></td>
<td>For this activity, the deliverable will consist on an exam, including conceptual questions and links between the studied subjects.</td>
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<td><strong>Specific objectives:</strong></td>
<td>To synthesize knowledge and to organize the study, so that the students can prioritize the study depth level in each subject.</td>
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</table>

| 2. Practical classes (CP) and project, activity or reduced-scope work (PR) | Hours: 45h  
Laboratory classes: 15h  
Self study: 30h |
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<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Support materials:</strong></td>
<td>Exercises and problems solved. Collection of exercise and problem statements to be solved by the students.</td>
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<tr>
<td><strong>Descriptions of the assignments due and their relation to the assessment:</strong></td>
<td>Delivery of a collection of solved exercises and problems, to be evaluated.</td>
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<tr>
<td><strong>Specific objectives:</strong></td>
<td>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.</td>
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| 3. Tutoring theoretical-practical studies (TD) and wide-scope project (PA) | Hours: 35h  
Guided activities: 15h  
Self study: 20h |
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<tr>
<td><strong>Description:</strong></td>
<td>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.</td>
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</tbody>
</table>
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.

Qualification system

Written test of knowledge (PE): 45%
Work done individually or in groups throughout the course (TR): 45%
Quality and performance of the group work (TG): 10%

Regulations for carrying out activities

PE: The examination will be held individually and consists of two parts: T, theory in which the student will not consult any documentation; and P, a problem in which the student may wish to consult the literature. During the exam, it will not be allowed the access to the internet nor the use of mobile phones.

TR: The evaluation will be done based on two kinds of activities: PR, collection of problems to be solved and delivered before the exam; and PA report on the proposed dimensioning of a complex installation, similarly to a biorefinery, or results of a numerical simulation study of a complex process such as co-digestion. Both activities will be conducted in groups of no more than three people.

TG: The quality and performance workgroup will be assessed on the basis of periodic presentations made by each subgroup focused on the progress of the project PA and/or on tutorial sessions.

Considering the individual qualifications for T, P, PR, PA and TG, all over 10, for calculating the final qualification (QF) the following expression will apply:

\[ QF = 0.45 \cdot (0.5 \cdot T + 0.5 \cdot P) + 0.45 \cdot (0.2 \cdot PR + 0.8 \cdot PA) + 0.1 \cdot TG \]

Students with QF less than 5 can be re-evaluated if the course-tasks were delivered on time. The final qualification of the re-evaluation will be the average of QF and the result of the re-evaluation exam.
Bibliography

Basic:


Complementary:


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