# Course guide
# 820746 - BMR - Biomass and Waste

**Last modified:** 16/05/2023

**Unit in charge:** Barcelona School of Industrial Engineering
**Teaching unit:** 724 - MMT - Department of Heat Engines.

**Degree:** **Academic year:** 2023 **ECTS Credits:** 2.5
**Languages:** English

## LECTURER

**Coordinating lecturer:** Velo Garcia, Enrique

**Others:** César Alberto Valderrama
Frederic Horta Sellarés
Pol Arranz Piera

## PRIOR SKILLS

- Stoichiometry of chemical reactions.
- Fundamentals of thermodynamics.
- Fundamentals of heat transfer.

## REQUIREMENTS

- Thermal equipment.

## 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-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal 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 course teaching methodologies are as follows:

- Lectures and conferences: knowledge exposed by lecturers or guest speakers.
- Participatory sessions: collective 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.
- 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: 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 by a group of students, and writing a report that should include the approach, results and conclusions.

Training activities:

The course training activities 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 (PS): learning based on presenting in the classroom an activity individually or in small groups.
- Theoretical/practical supervised work (TD): learning based on performing an activity in the classroom, or a theoretical or practical exercise, individually or in small groups, with the advice of the teacher.

Study activities
- Homework assignment of reduced extension (PR): learning based on applying knowledge and presenting results.
- Homework assignment of broad extension (PA): learning based on applying and extending knowledge.
- Self-study (EA): learning based on studying or expanding the contents of the learning material, individually or in groups, understanding, assimilating, analysing and synthesizing knowledge.

## LEARNING OBJECTIVES OF THE SUBJECT

The course focuses on technologies using biomass and waste as energy resource. In this area it is intended that students acquire the knowledge and skills necessary for describing and selecting equipment, as well as for calculating the performance of existing equipment and facilities, at a basic level. It is intended to provide an overview of the technologies and methods that will enable the student to make judgments, and studies of alternatives in the context of engineering projects.

Learning Outcomes

At the end of the course, the student:
- Is able to describe the role of biomass in the context of the energy system at the global and regional scale, its economic, social and environmental connotations, and the impact of technologies on a local and global context and is able to develop value judgments about the opportunities, threats and barriers on biomass utilization.
- Is able to list the relevant organizations, major projects at the international level, the main sources of information and regulations related to biomass technologies.
- Is able to carry out a basic engineering project related to energy supply using biomass technologies.
- Is able to propose a pre-feasibility study, related to the use of biomass-to-energy systems in different industrial and service sectors.
- Is able to describe the main lines of research in the field of biomass technologies and waste and is able to bring innovative ideas.

## STUDY LOAD

| Type | Hours | Percentage |
|---|---|---|
| Hours medium group | 15,0 | 24.00 |
| Guided activities | 5,0 | 8.00 |
| Self study | 42,5 | 68.00 |

**Total learning time:** 62.5 h

## CONTENTS

### 1. Biomass as energy resource

**Description:**
Definition of biomass.
Nature and types of biomass according to their composition.
Sources of biomass.
Biomass utilization for energy purposes.
Biomass utilization at local and global scale.
Regional and National policies promoting biomass utilization.

**Specific objectives:**
- The student understands the role of biomass as a renewable source of energy in production and service sectors, as well as its importance in the energy chain: processing, transportation, distribution and end-use of energy; and is able to develop value judgments about the opportunities, threats and barriers on biomass utilization.
- The student knows and understands the relevant organizations, major projects at the international level, the main sources of information and regulations related to biomass technologies.

**Related competencies :**
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.

**Full-or-part-time:** 6h
Theory classes: 3h
Self study : 3h

### 2. Characterization and properties.

**Description:**
Characteristics of biomass as a fuel
- Solids, liquids and gases
- Types of analysis
- Heating value

**Specific objectives:**
- The student knows and understands the main characteristics of biofuels and methods for determining their properties.
- The student has the knowledge and skills necessary for the determination of the energy characteristics of biofuels.

**Related activities:**
1. Exercise on characterization and properties of biofuels.

**Related competencies :**
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.

**Full-or-part-time:** 3h 30m
Theory classes: 0h 30m
Self study : 3h

### 3. Energy crops & forestry biomass

**Description:**
- Characteristics.
- Types of crops.
- Forest crops.
- Agricultural species.
- Strategic Projects.
- Policies for their development, and future prospects of energy crops.

**Specific objectives:**
- The student understands the role of energy crops in the context of the energy system at the global and regional scale, their economic, social and environmental connotations, and the impact of technologies on a local and global context and is able to develop value judgments about the opportunities, threats and barriers on their utilization.
- The student knows the main lines of research in the field of energy crops.

**Related competencies :**
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-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.

**Full-or-part-time:** 8h
Theory classes: 2h
Self study : 6h

### 4. Supply chain

**Description:**
- Theory of supply chain, strategic planning and its components.
- Stages of the chain, example of sustainability indicators.
- Configurations: technologies & efficiencies.
- Comparisons between configurations markets.
- Leading companies.

**Specific objectives:**
- The student understands the components of a biomass supply chain and their main characteristics.
- The student is able to make a preliminary design and and anlysis of a supply chain

**Related activities:**
2. Exercise on designing and planning a supply chain

**Related competencies :**
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-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.

**Full-or-part-time:** 11h
Theory classes: 1h
Self study : 10h

### 5. The combustion process with electricity and heat production

**Description:**
Fundamentals of combustion.
Heat and power using combustion technologies.
Burners and combustion equipment.
Heating and DHW
Power generation.
Other applications
Thermochemical Basis.
Energy analysis.

**Specific objectives:**
- The student is able to prepare a pre-feasibility study, related to the use of biomass combustion systems in different industrial and service sectors, by assessing the available resources.
- The student is able to carry out a basic engineering project related to energy supply using biomass combustion technologies.

**Related activities:**
3. Exercises on biomass combustion with electric and thermal energy production.

**Related competencies :**
CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal 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.

**Full-or-part-time:** 20h
Theory classes: 2h
Self study : 18h

### 6. Pyrolysis and gasification processes

**Description:**
Introduction
Opportunities and Future Prospects
Thermochemical principles
Classification of technologies
Electricity production by gasification
Pyrolysis processes

**Specific objectives:**
- The student is able to prepare a pre-feasibility study, related to the use of biomass gasification systems in different industrial and service sectors, by assessing the available resources.
- The student is able to carry out a basic engineering project related to energy supply using biomass gasification technologies.

**Related activities:**
4. Exercises about power generation by biomass gasification.

**Related competencies :**
CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal 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.

**Full-or-part-time:** 14h
Theory classes: 2h
Self study : 12h

### 7. Waste to energy

**Description:**
Environmental impacts of waste to energy (WTE) conversion plants
Types of feedstock for WTE systems and their characteristics
Waste to energy systems, engineering and technology
Pollution control systems for waste to energy technologies
WTE conversion plants in the framework of Circular Economy Policy

**Specific objectives:**
- The student is able to analyse and estimate the potential energy recovery from feedstock and the significant benefits that represent their valorisation in waste-to-energy systems.
- The student is able to evaluate a waste-to-energy conversion plant from a sustainable perspective.

**Related activities:**
Exercises devoted to estimate: the calorific value of waste-feedstock; the energy production and the emissions generated in waste-to-energy facilities.

**Related competencies :**
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.

**Full-or-part-time:** 7h
Theory classes: 2h
Self study : 5h

### 8. Legislation and regulatory frameworks

**Description:**
European regulations.
Spanish legislation.

**Specific objectives:**
- The student knows and understands the environmental connotations of the use of biomass and waste as energy sources and be able to make value judgments.
- The student knows the main regulatory frameworks for the use of biomass and waste as energy sources.

**Related competencies :**
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.

**Full-or-part-time:** 3h
Theory classes: 1h
Self study : 2h

**9. Socioeconomic aspects**

**Description:**
Social and economic impact.
Value Chain
Business Case Studies

**Specific objectives:**
- The student knows and understands the role of biomass in the context of the energy system at the global and regional scale, its economic, social and environmental connotations, and the impact of technologies on a local and global context and is able to develop value judgments about the opportunities, threats and barriers on biomass utilization.
- The student knows the policies of promotion of biomass as an energy resource and is able to critically analyse them.

**Related activities:**
5. Study visit

**Related competencies :**
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.

**Full-or-part-time:** 9h
Theory classes: 1h
Practical classes: 2h
Self study : 6h

## ACTIVITIES

**1. Exercises on characterization and properties of biofuels.**

**Description:**
Autonomous resolution of exercises about characterization and properties of biofuels

**Specific objectives:**
To deepen in the theoretical knowledge and its application to solve practical exercises on characterization and properties of biofuels.

**Material:**
Exercise statement
Bibliographic references and data sources.

**Delivery:**
Results report

**Related competencies :**
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.

**Full-or-part-time:** 4h 30m
Laboratory classes: 0h 30m
Guided activities: 2h
Self study: 2h

### 2. Exercise on designing and planning a supply chain

**Description:**
Group work on an exercise about designing and planning a supply chain (role game)

**Specific objectives:**
To deepen in the theoretical knowledge and its application to solve practical exercises on supply chains design and planning.

**Material:**
Exercise statement
Bibliographic references and data sources.

**Delivery:**
Results report

**Related competencies :**
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.

**Full-or-part-time:** 11h
Laboratory classes: 3h
Guided activities: 5h
Self study: 3h

### 3. Exercises on biomass combustion with electric and thermal energy production.

**Description:**
Autonomous resolution of an exercise about biomass combustion with electric and thermal energy production.

**Specific objectives:**
To deepen in the theoretical knowledge and its application to solve practical exercises on biomass combustion.

**Material:**
Exercise statement
Bibliographic references and data sources.
Solved examples

**Delivery:**
Results report

**Related competencies :**
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.
CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.

**Full-or-part-time:** 13h
Laboratory classes: 4h
Guided activities: 4h
Self study: 5h

### 4. Exercises about power generation by biomass gasification.

**Description:**
Autonomous resolution of an exercise about power generation by biomass gasification.

**Specific objectives:**
To deepen in the theoretical knowledge and its application to solve practical exercises on biomass gasification.

**Material:**
Exercise statement
Bibliographic references and data sources.
Solved examples

**Delivery:**
Results report

**Related competencies :**
CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal 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.

**Full-or-part-time:** 11h
Laboratory classes: 2h
Guided activities: 4h
Self study: 5h

### 5. Study visit

**Description:**
Visit to a biomass related business activity

**Specific objectives:**
To deepen in the knowledge of biomass related business models.

**Delivery:**
Visit report. Main conclusions and takeaways.

**Related competencies :**
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.

**Full-or-part-time:** 2h
Laboratory classes: 2h

**Exam**

**Description:**
Written exam

**Specific objectives:**
Assess the student attainment on the course learning outcomes, as a complement of the practical work done by the student during the semester.

**Delivery:**
The answers to the test questions, and the results of the exercises.

**Full-or-part-time:** 2h
Theory classes: 2h

## GRADING SYSTEM

35% Exam (PE)
15% Attendance and participation (AP)
50% Homework (TR)

## EXAMINATION RULES.

For the exam, the student may have only one sheet of paper with formulas and a programmable calculator.
The specific rules of individual and group work will be published in the teaching intranet

## BIBLIOGRAPHY

**Complementary:**
- BESEL, S.A. (Departamento de Energía). Biomasa: Cultivos energéticos [on line]. Madrid: IDAE (Instituto para la Diversificación y Ahorro de la Energía), 2007 [Consultation: 08/06/2014]. Available on: http://www.idae.es/uploads/documentos/documentos_10737_Biomasa_cultivos_energeticos_07_4bd9c8e7.pdf.
- McGowan, Tom. Biomass and alternate fuel systems : an engineering and economic guide [on line]. Hoboken, NJ: John Wiley & Sons, cop. 2009Available on: http://lib.myilibrary.com?id=277426. ISBN 9780470410288.
- Van Loo, Sjaak; Koppejan, Jaap. The handbook of biomass combustion and co-firing. London: Earthscan, cop. 2008. ISBN 9781844072491.
- Larson, Eric D. Sustainable bioenergy: a framework for decision makers [on line]. New York: UN-Energy, 2007 [Consultation: 08/06/2014]. Available on: ftp://ftp.fao.org/docrep/fao/010/a1094e/a1094e00.pdf. ISBN 9789211261271.
- Hildegard Lyko, Görge Deerberg, Eckhard Weidner. "Coupled production in biorefineries - Combined use of biomass as a source of energy, fuels and materials". Journal of Biotechnology [on line]. 142 (2009) 78-86 [Consultation: 08/02/2018]. Available on: https://www.sciencedirect.com/science/journal/01681656.- Knoef, H.A.M. [ed]. Handbook biomass gasification. 2nd ed. Enschede, the Netherlands: BTG Biomass Technology Group, 2012. ISBN 9789081938501.

## RESOURCES

**Other resources:**
International Energy Agency. Technology Roadmap: Bioenergy for Heat and Power. Release Date: 29 May 2012
http://www.iea.org/publications/freepublications/publication/2012_Bioenergy_Roadmap_2nd_Edition_WEB.pdf />
The European Technology Platform on Renewable Heating and Cooling (RHC-Platform). Biomass Technology Roadmap. Brussels, 2014
http://www.rhc-platform.org/fileadmin/Publications/Biomass_Technology_Roadmap.pdf />
World Energy Outlook
http://www.worldenergyoutlook.org/ />
REN21 RENEWABLES 2015. GLOBAL STATUS REPORT. Paris, 2015
http://www.ren21.net/wp-content/uploads/2015/07/REN12-GSR2015_Onlinebook_low1.pdf