Course guide
295109 - 295II024 - Sustainability and Circular Economy

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Unit in charge: Barcelona East School of Engineering
Teaching unit: 713 - EQ - Department of Chemical Engineering.

Degree: ERASMUS MUNDUS MASTER'S DEGREE IN ADVANCED MATERIALS SCIENCE AND ENGINEERING (Syllabus 2014). (Optional subject).
MASTER'S DEGREE IN CHEMICAL ENGINEERING (Syllabus 2019). (Compulsory subject).
MASTER'S DEGREE IN INTERDISCIPLINARY AND INNOVATIVE ENGINEERING (Syllabus 2019). (Compulsory subject).
MASTER'S DEGREE IN MATERIALS SCIENCE AND ADVANCED MATERIALS ENGINEERING (Syllabus 2019). (Compulsory subject).
ERASMUS MUNDUS MASTER'S DEGREE IN ADVANCED MATERIALS SCIENCE AND ENGINEERING (Syllabus 2021). (Optional subject).
ERASMUS MUNDUS MASTER IN HYDROGEN SYSTEMS AND ENABLING TECHNOLOGIES (HYSET) (Syllabus 2024). (Optional subject).

Academic year: 2025 **ECTS Credits:** 6.0 **Languages:** English

LECTURER

Coordinating lecturer: EVA GALLEGO PIÑOL

Others: Primer quadrimestre:
EVA GALLEGO PIÑOL - Grup: T11, Grup: T12, Grup: T13, Grup: T14
NÚRIA JIMÉNEZ GARCÍA - Grup: T11, Grup: T12, Grup: T13, Grup: T14
ILARIA LUCENTINI - Grup: T11, Grup: T12, Grup: T13, Grup: T14
DESIRÉE MARÍN NAVARRO - Grup: T11, Grup: T12, Grup: T13, Grup: T14
CESAR ALBERTO VALDERRAMA ANGEL - Grup: T11, Grup: T12, Grup: T13, Grup: T14

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEMCEAM-05. (ENG) Interpretar y aplicar normativas y especificaciones relativas a los materiales y sus aplicaciones
CEMCEAM-06. (ENG) Evaluar el tiempo de vida en servicio, la reutilización, la recuperación y el reciclaje de productos atendiendo a las características de los materiales que lo conforman
CEMUEQ-10. To adapt to the structural changes of society motivated by factors or phenomena of an economic, energetic or natural character and to contribute with technological solutions with a high commitment of sustainability
CEMUEII-06. Evaluate the sustainability of the proposed technological solutions and their associated risks to address a problem in a quantitative and objective manner, as well as propose schemes that favor the reutilization of resources and the circular economy.

Generical:
CGMUEQ-01. Ability to apply the scientific method and the principles of engineering and economics, to formulate and solve complex problems in processes, equipment, facilities and services, in which the matter undergoes changes in its composition, state or energy content, characteristic of the chemical industry and other related sectors among which are the pharmaceutical, biotechnological, materials, energy, food or environmental
CGMUEQ-06. Have the capacity to analyze and synthesize the continuous progress of products, processes, systems and services using safety, economic viability, quality and environmental management criteria
CGMUEQ-07. Integrate knowledge and face the complexity of making judgments and decisions, based on incomplete or limited information, including reflections on the social and ethical responsibilities of professional practice
CGMUEII-03. Analyze the economic, social and environmental impact of technical solutions to base strategic decisions on criteria of objectivity, transparency and professional ethics.

Transversal:
02 SCS. SUSTAINABILITY AND SOCIAL COMMITMENT. Being aware of and understanding the complexity of social and economic phenomena that characterize the welfare society. Having the ability to relate welfare to globalization and sustainability. Being able to make a balanced use of techniques, technology, the economy and sustainability.
03 TLG. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.

LEARNING RESULTS

Knowledges:
K03. Demonstrate an understanding of the hydrogen value chain, including hydrogen production processes and technologies, hydrogen storage technologies, hydrogen transport/logistics/infrastructure, hydrogen end uses (stationary, mobility, industrial and residential, including fuel cells), hydrogen safety, codes and standards, and all socioeconomic issues related to the energy transition, partly driven by the use of hydrogen.
K01. Conceive, analyse, design, size, optimise and exploit hydrogen technologies and processes, with a focus on both technology and systems.
K02. Demonstrate in-depth knowledge of standards related to the safety of working with hydrogen, the integration of systems related to hydrogen technologies, and market potential.

Skills:
S01. Communicate effectively with others orally, in writing and graphically about learning, thought processes and decision making, and participate in discussions, using interpersonal skills such as active listening and empathy that support teamwork.
S02. Work in the field as well-trained, enthusiastic professionals with a broad multidisciplinary knowledge of hydrogen technologies and systems, educated in an international and multicultural environment to promote global cooperation in meeting the complex challenges of the energy transition.
S04. Apply an understanding of advanced digital technologies with a critical perspective in a range of academic, professional, social and personal contexts, such as data analysis, multiscale modelling, techno-economic analysis and environmental systems analysis.

Competences:
C01. Recognise the complexity of the economic and social phenomena typical of a welfare society in order to relate welfare to globalisation and sustainability, and use techniques, technology and principles of economics and sustainability in a balanced and compatible way.
C02. Work as part of a multidisciplinary team, whether as a team member or in a leadership role, to contribute to the development of projects with pragmatism and a sense of responsibility, undertaking commitments with due regard to the resources available.
C05. Propose advanced scientific and technological solutions to complex industrial challenges in the field of energy, with a focus on the use of hydrogen as a vector.

TEACHING METHODOLOGY

The following activities will be carried out, either in or outside the classroom, in the development of the course:

1. Lectures, participative sessions and problem solving sessions
2. Homework and assignments
3. Project
4. Mid-term and final Exam

Detailed project information regarding the scope, content, format, deadlines, etc., will be presented in an attached document.

The methodology designed for this course is the Project based learning (PBL), the students would use OpenLCA software and the support of an OpenLCA trainer

Invited speakers are experts who work on sustainable assessment and can participate in the definition of the system and supervising the progress of the teams.

Visits to enterprises that apply circularity to their processes and activities will be done

LEARNING OBJECTIVES OF THE SUBJECT

At the end of the course the student will be able to:
• Distinguish between the concepts of the use of resources and efficiency in terms of sustainable development and the linkage of thermodynamics science and environmental impact.
• Perform a sustainable assessment of a technological system by using life cicle assessment tools.
• Demonstrate a good knowledge and understanding of the tools used for sustainability analysis with emphasis on carbon footprint, Life cycle assessment and Life cycle costing.
• Evaluate the technological, environmental and economic feasibility of a system through the life cycle perspective.

STUDY LOAD

Type	Hours	Percentage
Self study	96,0	64.00
Hours large group	27,0	18.00
Hours small group	13,5	9.00
Guided activities	13,5	9.00

Total learning time: 150 h

CONTENTS

1. Introduction to Circular Economy

Description:
Definition and principles. Key characteristics and enabling factors of a circular economy. Resource, environmental, economic and social benefits of circular economy. Circular economy in the European and global context. Revalorisation of waste to energy, products. Description of the main routes of characterization of wastes/raw materials to quantify their energetic or material valorisation potential.

Specific objectives:
The student will develop a basic understanding of the concept of circular economy and its potential application in the framework of the European context.
The student will learn how to characterize wastes and how they can be revalorized according to its properties in a circular economy context

Related activities:
Homework assignment: Short exercises

Full-or-part-time: 10h
Theory classes: 6h
Guided activities: 2h
Self study : 2h

2. Sustainability

Description:
Sustainability. Novel accounting methods (LCA perspective).

Specific objectives:
Introduction to sustainability: worldwide trends in respect to environment, economy and equity. Drivers for change to more sustainable models. UN SDG. Sustainability and circularity interaction: Life cycle thinking

Related activities:
Homework assignment: Short exercises

Full-or-part-time: 4h
Theory classes: 2h
Self study : 2h

3. Methodologies of economic and environmental evaluation (LCA/LCC) in relation to sustainability

Description:
LCA target audience and applications. LCA framework, goal and scope. Inventory analysis, allocation Impact assessment. Carbon footprint methodology. LCC as complement of LCA. LCC methodology. Key concepts of LCC.

Specific objectives:
The student will be able to identify the different stages of a life cycle analysis and how to align the economic issues associated through the LCC.
The student will be able to develop a basic inventory from a system/industrial process and to perform a carbon footprint analysis, as well as the determination of other possible mid-point impacts (e.g. acidification, euthrophication, land use, human toxicology, etc.)

Related activities:
Homework assignment: Short exercises
Project: LCA and carbon footprint analysis using OpenLCA sortware

Full-or-part-time: 14h
Theory classes: 8h
Guided activities: 4h
Self study : 2h

4. Social life cycle assessment (S-LCA)

Description:
Social issues related to business and products. Social assessment framework, guidelines and methods (S-LCA Methodologies). Identification of S-LCA impact categories and indicators.

Specific objectives:
The students will be able to develop a step-by-step S-LCA analysis of a case study for a product system.

Related activities:
Co-operative learning approach based on a case study of S-LCA.

Full-or-part-time: 6h
Theory classes: 2h
Guided activities: 2h
Self study : 2h

5. Waste processing technologies for the production of energy

Description:
Introduction to waste to energy (WtE) conversion. WtE conversion plants in the framework of Circular Economy Policy. WtE technology options: co-processing, anaerobic digestion, landfill gas collection, thermal treatment of municipal solid waste (MSW), pyrolysis / gasification, incineration. Types of feedstock for WtE systems and their characteristics. WtE systems, engineering and technology: Pre- processing and treatment of municipal solid waste
(MSW) prior to incineration, Municipal solid waste (MSW) combustion plants, Waste firing in large combustion plants, WtE systems for district heating. Environmental impacts of WtE conversion plants. Pollution control systems for waste to energy technologies.

Specific objectives:
The student will be 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 will be able to evaluate a waste-to-energy conversion plant from a sustainable perspective

Related activities:
Homework assignment: Short exercises related to WtE
Project: Conversion of Municipal Solid Waste (MSW) to produce Electricity

Full-or-part-time: 10h
Theory classes: 4h
Guided activities: 2h
Self study : 4h

6. Solid waste processing technologies for the production of products

Description:
Solids wastes are generated in large extension in the industrial and urban cycles and processing routes to recover added values or by-products will be developed. Definition of treatment flow-sheets identification of treatment or processing technologies, development of associated mass and energy balance will be defined. Routes of valorisation for different industrial applications will be selected and requirements of quality will be provided.

Specific objectives:
The student will be able to analyse and estimate the potential material recovery from solid wastes and the significant benefits that represent their valorisation in waste-to-products systems.

Related activities:
Project: Inclusion of waste to product aspects

Full-or-part-time: 12h
Theory classes: 4h
Guided activities: 4h
Self study : 4h

7. Water regeneration and recycling technologies

Description:
Water in the context of circular economy. Current water resources and uses. Alternative hydric resources. Water regeneration and recycling. Water treatment technologies. Membrane-based technologies. Innovative hybrid systems. Industrial wastewater valorisation and reuse. Potential circularity in water sector. Industrial symbiosis.

Specific objectives:
The student will learn which routes and technologies are available today for the regeneration and reuse of wastewater in a circular economy context.

Related activities:
Activity 1: Solving problems related to the unit content.

Full-or-part-time: 12h
Theory classes: 4h
Guided activities: 4h
Self study : 4h

8. Urban Energy Sustainability and Smart Cities

Description:
Cities are complex entities, in which numerous actors and diverse scenarios are superimposed. Urban energy sustainability should be aimed at improving the balance of raw material flows and the production of waste/pollutants, which will unfailingly improve urban habitability, as well as favour the global goals of sustainable development. Indicators for Urban Energy Sustainability are presented. Smart energy systems are analysed and the concept of Smart Cities is presented.

Specific objectives:
The student will learn to evaluate Urban Energy Sustainability and impact of Smart Cities.

Related activities:
Activity: Solving problems related to the unit content.

Full-or-part-time: 3h 40m
Theory classes: 1h 40m
Guided activities: 1h 20m
Self study : 0h 40m

9. Management tools for circular economy

Description:
Business models, market analysis and management tools. LCA as a business opportunity. Value creation ecosystem. Business model canvas. Strategy canvas. Innovation and enterpreneurship.

Specific objectives:
The student will learn different business models, market analysis and management tools for its application to circular economy and LCA evaluations.

Related activities:
Project: Inclusion of business models applied to LCA in the project

Full-or-part-time: 7h 20m
Theory classes: 3h 20m
Guided activities: 2h 40m
Self study : 1h 20m

GRADING SYSTEM

The final grade is determined according to the following equation:

Final grade = MEX*0.17+FEX*0.23+HOM*0.17+PRO*0.43
Homework and assignments (HOM)
Project (PRO)
Mid-term (MEX)
and final Exam (FEX)

The overall mark of the Project for each student will consider the weighted marks of the deliverables given by the supervising professors (80%) as well as the average marks derived from the self-evaluations and the evaluations of the group peers from each deliverable (10%), and the average group's marks derived from the overall assessment of the work done in each deliverable (10%).

In this course there is no retake exam and since the learning methodology is project-based learning, the project activity should be carried out throughout the semester to pass the course.

BIBLIOGRAPHY

Basic:
- Dinçer, Ibrahim; Rosen, Marc A. Exergy : energy, environment, and sustainable development [on line]. Amsterdam ; Boston: Elsevier, 2007 [Consultation: 21/04/2020]. Available on: https://www.sciencedirect.com/science/book/9780080445298. ISBN 9780080531359.
- Hunkeler, David; Lichtenvort, Kerstin; Rebitzer, Gerald. Environmental life cycle costing [on line]. Pensacola, Fla.: SETAC, 2008 [Consultation: 21/04/2020]. Available on: https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=570462. ISBN 9781420054736.
- Klinghoffer, Naomi B.; Castaldi, Marco J. Waste to energy conversion technology [on line]. Oxford: Elsevier Science & Technology, 2013 [Consultation: 21/04/2020]. Available on: https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=1574937. ISBN 9780124051904.

RESOURCES

Other resources:
• Spire Circular Economy Road-Map: https://www.spire2030.eu/intro />• EU Circular economy Road Map: https://ec.europa.eu/growth/industry/sustainability/circular-economy_en />• Scientific papers from different databases: Science Direct, Scopus
• Use the remote access to the UPC library: https://apps.bibliotecnica.upc.edu/discovery/bases_dades/ />• Energy Ebook Package Springer Link: http://link.springer.com/search?facetcontenttype=% />• 22Book%22&package=40367&showAll=false
• SHDB tutorial: https://www.youtube.com/watch?v=WTLlhrSr4aU&t=517s
• Social Hotspots Database (SHDB) tutorial: https://www.youtube.com/watch?v=WTLlhrSr4aU&t=517s />• UNEP-SETAC, United Nations Environment Programme (UNEP) (2009), Guidelines for social life cycle assessment of products. UNEP/SETAC Life Cycle Initiative. Available at: http://www.unep.org/pdf/DTIE_PDFS/DTIx1164xPA-guidelines_sLCA.pdf
• UNEP-SETAC (2013) The methodological sheets for subcategories in Social Life Cycle Assessment. Available at: https://www.lifecycleinitiative.org/wp-content/uploads/2013/11/S-LCA_methodological_sheets_11.11.13.pdf
• GRI (2011) Sustainability Reporting Guidelines" Global Reporting Initiative https://www.globalreporting.org/resourcelibrary/G3.1-Guidelines-Incl-Technical-Protocol.pdf