Module name: Energy and Green Production II: New Processes, Biorefinery, Green Hydrogen

Module number: B 3		**ECTS credit points: 5**
Academic level	Master	
Intended curriculum phase	2nd sem.	
Compulsory module or compulsory elective module	Compulsory module	
Ratio of in-person/online teaching	1.5 in-person teaching	3.5 online teaching
Assigned courses*/ stages / ECTS credit points *... Course types and associated workloads are explained in detail under planned didactics and methodology	1. Introduction to Transition from Linear to Circular Economy (Grundlagen des Übergangs vom derzeitigen linearen Wirtschaftssystem zu einer künftigen Kreislaufwirtschaft), Biorefineries (Konzept der Bioraffinerien); e-learning course – **online stage**, 1.5 ECTS credit points 2. Energy and Production II – New Processes, Biorefinery, Green Hydrogen; lecture / case studies – **in-person stage**, 1.5 ECTS credit points, VU (lecture with integrated exercises) 3. Transfer Project; e-learning project – **transfer stage**, 2 ECTS credit points, PT (project)	
Scope	5 ECTS credit points	
Required skills/modules; skills/modules to be acquired in parallel	Energy and Green Production I	
Prerequisite for	none	
Course language	English	
Central idea and skills to be imparted	In this module, based on the global challenges of future energy supply due to dwindling reserves of cheap fossil energy and taking into account climate protection goals, students learn about possible energy supply scenarios and the framework conditions for new technologies for the optimal use of renewable raw materials in the production of goods. The module addresses both the technical challenges of transitioning to a renewable, zero-emission energy system with	

	a focus on high-efficiency electrochemical energy conversion and energy storage, as well as the fundamentals of green engineering and green chemistry. In an energy system based on renewable energy sources, energy storage will be disproportionately more important than it is today. For this purpose, students gain basic knowledge of selected technologies for storing and transporting energy. They learn the fundamentals of technological solutions such as Power to X (hydrogen, methane, etc.) and develop and discuss possible applications. The production and use of climate-neutral hydrogen as an energy source and as a raw material in industry are demonstrated using specific examples. Green engineering and green chemistry provide the tools for the transition from the current linear economy to a future circular economy. In addition to the consumers, close attention is paid to the processing industry. Industries that are not based on bio-based raw materials must also join the circular economy for the manufacture of goods. In particular, the concept of biorefineries, possible raw materials, their characterisation, conversion and fractionation are explained. Using exercises, case studies and calculation exercises, students are able to apply the knowledge and skills acquired. After successfully completing the module, students are able to carry out independent analyses of technological options for efficient and environmentally friendly energy supply and raw material processing and to determine the advantages of using or substituting environmentally harmful raw materials in production.

Teaching content	**Learning outcomes / goals**
	Upon successful completion of the module, students are able to:
Global challenges of future energy supply - Reduction of CO_2 emissions - Energy storage technologies - Clean technologies for power generation Energy transport and energy storage - Energy transport efficiency - Media and technologies for transporting and storing energy Green engineering and green chemistry	• derive future energy supply system scenarios and their effects on the environment • derive solution strategies for an energy system that achieves climate protection goals • identify technical challenges of an energy system based on renewable energies • explain technologies for the production and use of climate-neutral hydrogen • derive solution strategies for the efficient transport of non-fossil energy • analyse and evaluate electrochemical technologies • evaluate energy storage technologies in terms of efficiency, cost and applicability

Selected energy storage technologies - Hydrogen - Fuel cells and electrolyser - Accumulators - Redox flow systems - Power to X Renewable raw materials - Characterisation - Conversion - Fractionation Exercises, case studies, calculation exercises	• explain the current economic system and the goal of a circular economy • implement the principles of green engineering and green chemistry in the individual sphere of activity • name renewable raw materials and their characteristics • describe conversion technologies and use them in the individual sphere of activity • describe the state of the art of fractionation processes, explain processes and evaluate them in the individual sphere of activity based on mass and energy balances • carry out simple analyses with renewable raw materials or with industrial process streams • carry out a technology assessment based on comprehensive knowledge of the physical/chemical properties of the process flow/raw material to be processed • carry out simple mass and energy balances

Teaching and learning activities and methods*

*... teaching and learning activities and methods along with their structuring are explained under planned didactics and methodology

Planned didactics and methodology:

In-person teaching units:
- The in-person stage is conducted as a mixture of front-of-class, question-based and discussion-based teaching and with much time devoted to joint discussion (whole-class, in groups).
- Examples to illustrate and consolidate the teaching content are used.
- Flipped classroom elements

Project:
- Group work
- Self-directed learning
- Independent preparation and follow-up of the teaching content
- Application of the teaching content in practice-relevant tasks

Distribution of ECTS credit points:

	Estimated time commitment in units of 60 minutes
In-person teaching units	25
Course assessment	50
Project	50
Total	**125**

Assessment	Assessment methods and criteria:

Assessment methods and criteria:

The in-person stage is assessed by means of a written examination and by preparing and presenting a group task (case study discussions).

Weighting of the individual assessments in the overall assessment of the module:

	Weighting	Minimum required positive assessment for a completion of the course on the first try
Written exam – in-person stage	50%	**> 50%**
Project report, project work	30%	**> 50%**
Project presentation	20%	**> 50%**
Total	**100%**	**> 50%**

Any deviations from this description of the overall assessment are announced at the beginning of the module.

Specialist literature and other learning materials

Secondary literature: Books, each in the current edition:

- IEA (2021): *World Energy Outlook 2021*, Paris: IEA. See: https://www.iea.org/reports/world-energy-outlook-2021.
- Hacker, V.; Mitsushima, S. (ed.) (2018): *Fuel Cells and Hydrogen, From Fundamentals to Applied Research*, Amsterdam: Elsevier. ISBN: 9780128114599

Other learning materials:

- TU Graz learning videos (20-30 min.)
- screencasts and slidecasts
- PPT slides