M.Sc.

Hydrogen Technology

Dean of Studies: Prof. Dr.-Ing. Johannes Völkl

Valid for winter semester 2024/2025

(SPO 20231)

Module catalogue

This version is under constant development by the responsible lecturer. It is applicable to lectures, lab or computer courses. All regulations and provisions are in accordance with the university study regulations.

approved by the Faculty Council on 3rdh of July, 2024

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Study and examination regulations

The current valid study and examination regulations of the University of Applied Science Rosenheim can be found on the homepage:

https://www.th-rosenheim.de/home/infos-fuer/studierende/studienorganisation/formalia/studienregelungen/studien-und-pruefungsordnungen/

Programme content and organization

Programme description

The reduction of climate gases and the establishment of a sustainable economy is a common goal of both politics and society. Especially, the chemical industry will encounter a huge transformation when process routes switch to sustainable energy and raw materials. Certainly, this development is not limited to this industry but will effect all sectors.

The master's programme Hydrogen Technology is developed to give students an application-oriented education focused on Hydrogen. The goal is to deepen and specialize one's knowledge in production, storage, transport and application of Hydrogen, and related fields. The programme offers modules to gain in-depth technological as well as applied and competence-oriented knowledge. The theoretical base is supplemented with a project within the area of Hydrogen Technology and current challenges of applied research and development projects.

To achieve this goal the programme is organized as a combination of compulsory fundamental modules; specialization modules with a stronger theoretical background; application and competence-oriented modules; as well as a project thesis including a project seminar. The programme is completed with a master's thesis.

All students must take the compulsory modules HTF 01 "Fundamentals of Hydrogen and Safety" and HTF 02 "Scientific methods and writing." This corresponds to 10 CP.

From the Specialization and Application & Competence-oriented Elective Modules a total of 40 CP must be earned to complete the programme. One must select at least 10 CP from the Specialization group and 10 from the Application & Competence-oriented group. The modules and their assignment to these groups are summarized in this module handbook and may be updated by the faculty board.

The theoretical foundation is supplemented by a project thesis, with an accompanying project seminar, on topics from the area of Hydrogen Technology and current challenges of applied research and development projects. This corresponds to 10 CP.

The independent and creative application of knowledge on a problem from Hydrogen Technology is demonstrated in the master's thesis at the end of the programme. The thesis is worth a total of 30 CP.

Upon request, other modules from the range of courses offered by Rosenheim Technical University of Applied Sciences or other universities can also be selected and credited as required elective modules. The Examination Committee decides on the request and the allocation as a specialist required or application and skill-oriented required elective module.

Recommended programme organization

Table 1: Recommended programme organization

Semester	Module number	Module name	Module group	CP
1	HTF 02	Scientific Methods and Writing	Compulsory	5
	HTS		Specialization	10
	HTS		Application & Competence-oriented	10
2	HTF 01	Fundamentals of Hydrogen and Safety	Compulsory	5
	HTS		Specialization	10
	HTS		Application & Competence-oriented	10
	HTM 01	Project Thesis		10
3	HTM 02	Master's Thesis		30
Total				**90**

At least 10 CP must be earned from the module group "Specialization."

At least 10 CP must be earned from the module group "Application & Competence-Oriented."

In total, 40 CP must be earned from the groups "Specialization" and "Application & Competence-Oriented."

Elective modules

In the following the modules, which can be selected in the “Hydrogen Technology” master’s programme are listed. Besides the compulsory courses the courses are classified into the following groups:

- Specialization
- Application & Competence-Oriented

The course listed in Table 2 and 3 show the current classification of courses and whether the course is being held in summer or winter semester.

In accordance with §5 of the study regulations, it is possible to select courses from the catalogue of the University of Applied Science Rosenheim or other Universities, which are not listed in Table 2 and 3. This selection must be approved by the programme’s examination board. The approval must be carried out for each student individually. These courses must match the technical and academic profile of the “Hydrogen Technology” master’s programme. Students receive information from the examination board in advance, if the selection is approvable. The corresponding application for approval can be found on the homepage of the master’s programme.

Table 2: Module list in winter term

Module		Compulsory group	Specialization group	Application & Competence-oriented group
HTF 01	Fundamentals of Hydrogen and Safety	X		
HTS 01	Chemical H_2 Conversion: Applications and Industrial processes			X
HTS 02	Homogeneous Catalysis			X
HTS 06	Hydrogen Storage, Transport and Distribution Systems		X	
HTS 09	Energy Technologies			X
HTS 11	Computational Fluid Dynamics for Process Industry		X	
HTS 12	Membrane Technologies		X	
HTS 13	Heterogeneous Catalysis			X

Table 3: Module list in summer term

Module		Compulsory group	Specialization group	Application & Competence-oriented group
HTF 02	Scientific Methods and Writing	X		
HTS 04	Advanced Thermodynamics for Hydrogen Applications		X	
HTS 05	Sources and Generation of Hydrogen		X	
HTS 03	Energy Politics and Laws			X
HTS 07	Electrochemical Process Engineering		X	

HTS 08	Techno-economic Analysis and Simulation	**X**
HTS 10	Introduction to the Economics of Hydrogen Markets	**X**

Regulations and Provisions

Project thesis with project seminar

A list of possible project topics is provided in the learning campus. The student contacts supervisors early to discuss details of the topic and to define the scope of the work. The start of a topic not present on the list is possible. All project theses deal with challenges in the field of Hydrogen Technology. A summary of the regulations and provisions is shown in Table 4.

Table 4: Regulations and provisions for the project thesis

Topic generation	A list of project topics is given in the learning campus. Details and the specific scope are to be discussed with the supervisors. The title does not need to be in the project list.
Thesis application	The student has to apply for the allocation of the topic to the regulation board after the student and the supervisor agree on a topic and its scope. The application form is in the learning campus. The application procedure is shown in Figure 1.
Duration	After admission of the topic by the regulation board the maximum duration is 5 month from the date of the admission.
Examiner	The student nominates an examiner and a second assessor for the project thesis in the application process. The nomination is approved by the examination board. The examiner is responsible for the assessment of the project thesis.
Examinations	The project thesis with project seminar consists of one Admission Requirement and two successful examinations. • Admission Requirement: The discussion of the topic with the main supervisor to agree on a topic is completed with the signature of the supervisor of the application form. This discussion is the admission requirement to start the project thesis. • Oral Examination: after completion of the tasks of the project thesis the results are presented. This examination consists of 20 minutes of presentation and 10 minutes of discussion. The examination is held after completion, the date will be determined together with examiner. It has to be within the maximum duration period of the project thesis. As an alternative, the presentation can also be given as part of an academic or technical conference in the presence of the examiner.

- Written project thesis: the thesis is submitted as a written scientific report. The submission deadline is defined in the application form for the project topic. The deadline should be in the semester term in which the project thesis was started. The report should be submitted in a digital format such as a pdf-file.
- Weight of the grade: 90 % written report / 10 % oral examination.
- In the final grading report only the combined final grade will be included

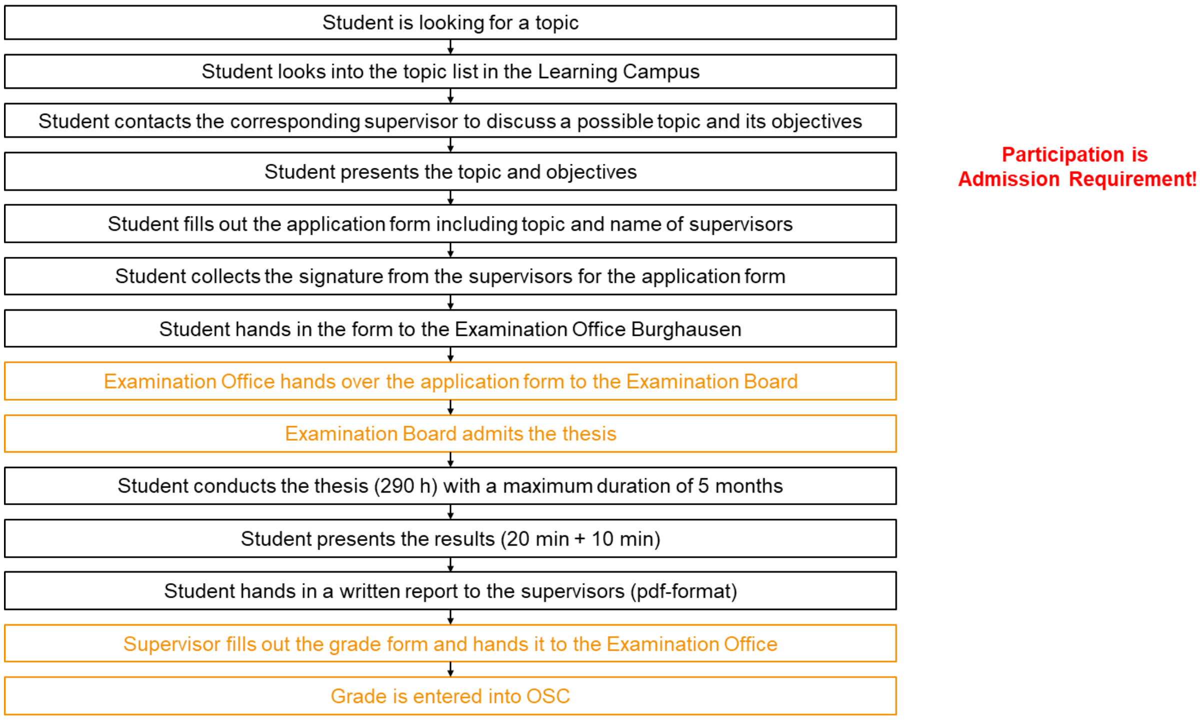

Figure 1: Process for application and subsequent procedures for the Project Thesis

Module catalogue

Compulsory Modules

HTF 01: Fundamentals of Hydrogen and Safety

Module Responsible	Prof. Dr.-Ing. Patrick Preuster
Lecturer	Prof. Dr.-Ing. Patrick Preuster, Prof. Dr.-Ing. Wolfgang Arlt
Module Group	Compulsory
Module Duration	1 semester
Term	Winter
Applicability of the module in the degree program	Mandatory subject in HYT-Master
Course Type	• Lecture: 80% • Practical Course: 20%
Credit Points (ECTS)	5
Weekly Working Hours	4
Total Workload	150 hours
Prerequisites	Fundamental understanding of (chemical) engineering
Learning Goals	After the course students • understand the thermodynamic characteristics of hydrogen • understand are able to describe physical hydrogen storage technologies e.g. liquefaction and compression • are able to conduct a risk assessment on hydrogen-based applications and know how to handle typical risks and evaluate hazards • know general methods of hydrogen generation • know the different technologies of hydrogen storage and transportation
Content	• Repetition of (chemical) engineering fundamentals

	• Fundamental properties of Hydrogen • Thermodynamic characteristics of Hydrogen and its applications • Safety topics regarding the handling, storage and transport of Hydrogen • Overview of hydrogen generation methods •
Material	Lecture notes as downloadable files (learning campus)
Examination	Admission requirements, type and duration according to Study Regulations (SPO), updated at the beginning of each term, announcements published by the examination office
Literature	Specific literature for each chapter, current papers, will be announced during lectures

HTF 02: Scientific Methods and Writing

Module Responsible	Prof. Dr.-Ing. Johannes Völkl
Lecturer	vhb-Course
Module Group	Compulsory
Module Duration	1 semester
Term	Winter / Summer (starting summer term 2023)
Applicability of the module in the degree program	Mandatory subject in HYT-Master
Course Type	• Lecture: 60% • Practical Course: 40%
Credit Points (ECTS)	5
Weekly Working Hours	
Total Workload	150 hours
Prerequisites	
Learning Goals	"Scientific Writing" in English is a crucial qualification course for students of all disciplines and all skill levels (Bachelor's, Master's, PhD). Specifically for students of natural sciences who are often required to draft texts in English (ranging from letters & e-mails about papers, to abstracts, to posters, to scientific publication and third party applications), this course shall not only help them encounter the "fear of blank page", but also help them overcome the language barrier. The online seminar "Scientific Writing" aims at targeting students of natural sciences and health sciences who wish to improve their academic writing skills in English. The course navigates from dealing with basic linguistic features to complex expertise of academic writing. Initially the course deals with the first steps of scientific writing, the phase of preparation of the article. The course explains how to search and manage the scientific literature as well as how to plan the writing process. In a second phase, the course guides through the writing process itself. After dealing with important aspects of English language and expression in scientific writing, the course offers learning units that help in acquiring expertise in drafting various parts of a scientific publication. Additionally, these learning units offer a step-by-step opportunity to compose one's own scientific

	publication. In a third phase, the course explains how to publish and present a scientific publication. In this part of the course students can acquire knowledge not only regarding the procedure of submitting an article to a journal, but also concerning the oral and poster presentation of the scientific publication. The objective of the seminar is to provide a brief theoretical introduction on each topic of the course. Exercises with clearly defined tasks give students the opportunity to test what they have learned and applied directly during the flow of the seminar. Immediate feedback from the tutor can help the students with their queries if they are stuck. The learning objectives are specified at the end of each class. The lectures shall be held independent of other events and shall be open to audiences of all types.
Content	PREPARATION OF THE ARTICLE 1. Introduction 2. Literature search 3. Literature management 4. Planning of the writing process THE WRITING PROCESS 5. Language and Expression 6. Methods 7. Introduction and Aims 8. Results 9. Discussion and Conclusion 10. Title and Abstract 11. Visuals 12. Bibliography and Citation PUBLISHING AND PRESENTING 13. Submission to the journal 14. Oral presentation 15. Poster presentation 16. Peer-reviewing
Material	
Examination	Admission requirements, type and duration according to Study Regulations (SPO), updated at the beginning of each term, announcements published by the examination office
Literature	Specific literature for each chapter, current papers, will be announced during lectures

HTM 01: Project Thesis with Project Seminar

Module Responsible	Prof. Dr.-Ing. Johannes Völkl	
Lecturer	Nominated by the examination board	
Module Group	Compulsory	
Module Duration	1 semester	
Term	Winter	
Applicability of the module in the degree program	Mandatory subject in HYT-Master	
Course Type	Project thesis with presentation in a project seminar	
Credit Points (ECTS)	10	
Weekly Working Hours		
Total Workload	Total	300 hours
	Project thesis work:	290 hours
	Seminar with own presentation:	10 hours
Prerequisites	None	
Learning Goals	The learning goals should include the following competencies as defined by “Qualifikationsrahmen für die Deutschen Hochschulabschlüsse” for master’s programs in Germany: • Instrumental Competencies Knowledge and understanding as well as competencies for solving problems in new situations • Systemic competencies ○ Dealing with complex challenges ○ Making decisions based on academic and scientific principles, even under uncertainties ○ Acquiring new knowledge independently ○ Working independently on an extensive academic and scientific topic • Communication competencies	

	○ Present one's own scientific conclusions to an audience of experts and non-experts in a clear and meaningful way ○ Discuss scientific topics, challenges and ideas with experts and non-experts The project report and presentation are supporting the general study goal of generating and deepening language, presentation and communications skills. Collaborative skills are trained by working on a scientific topic with other people and discussing challenges and results within a project team.
Content	• Literature research • Definition of the problem to be solved • Planning of experiments and steps to solve the problem • Experimental work and/or academic research • Preparation of a project report and a project presentation
Material	Material provided by the supervisor, own research
Examination	• Oral Examination: A seminar presentation of the project thesis in the course's project seminar is required. This examination consists of 20 minutes of presentation and 10 minutes of discussion. The examination is held during the lecture term. The seminar date is assigned by the student secretary in coordination with the supervisor. As an alternative, the presentation can also be given as part of an academic or technical conference in the presence of the examiner. • Written project thesis: The thesis must be handed in as a written scientific report. The submission deadline is defined with the application form for the project topic. The deadline should be within the semester term in which the project thesis was started. The report should be submitted in a digital format, such as a pdf-file.
Literature	

HTM 02: Master's Thesis

Module Responsible	Prof. Dr.-Ing. Johannes Völkl
Lecturer	Nominated by the examination board
Module Group	Compulsory
Module Duration	1 semester
Term	Winter / Summer
Applicability of the module in the degree program	Mandatory subject in HYT-Master
Course Type	Master's thesis
Credit Points (ECTS)	30
Weekly Working Hours	
Total Workload	Total 900 hours
Prerequisites	30 CP required to apply for a thesis topic (according to study regulations of the "Hydrogen Technology" master's program)
Learning Goals	The learning goals include the following competencies as defined by "Qualifikationsrahmen für die Deutschen Hochschulabschlüsse" for master's programs in Germany: • Instrumental Competencies Knowledge and understanding as well as competencies for solving problems in new situations • Systemic competencies ○ Dealing with complex challenges ○ Making decisions based on academic and scientific principles, even under uncertainties ○ Acquiring new knowledge independently ○ Working independently on an extensive academic and scientific topic • Communication competencies ○ Present one's own scientific conclusions to an audience of experts and non-experts in a clear and meaningful way

	○ Discuss scientific topics, challenges and ideas with experts and non-experts The report and presentation of the results of the master's thesis support the general study goal of acquiring and deepening language, presentation and communication skills. Collaborative skills are trained by working on a scientific topic with other people and discussing challenges and results within a project team.
Content	• Literature research • Definition of the problem to solve • Planning of experiments and steps to solve the problem • Experimental work and/or academic research • Preparation of a report and presentation
Material	Material provided by the supervisor, own research
Examination	• Oral Examination: The oral examination is a presentation of the thesis within the course's project seminar. This examination consists of 20 minutes of presentation and 10 minutes of discussion. The seminar date is assigned by the supervisor in coordination with the student. • Written thesis: The thesis is a written scientific report. The submission deadline is defined in the application form. The report is submitted via OSC platform of TH Rosenheim. • In accordance to the study regulations the ratio of the weight for the final grade is 90 % written report / 10 % oral examination
Literature	

Module Group: Specialization and Application & Competence-Oriented

HTS 01: Chemical H_2 Conversion: Applications and Industrial Processes

Module Responsible	Prof. Dr.-Ing. Johannes Völkl
Lecturer	Prof. Dr.-Ing. Johannes Völkl
Module Group	Application & Competence-Oriented
Module Duration	1 semester
Term	Winter
Applicability of the module in the degree program	MF 38 Chemical H2 Conversion
Course Type	• Lecture: 50% • Practical Course: 50%
Credit Points (ECTS)	5
Weekly Working Hours	4
Total Workload	150 hours
Prerequisites	Basic knowledge in Chemistry, Thermodynamics and (Process) Modeling
Number of Participants	Not limited
Learning Goals	After the module students • know different Hydrogen conversion routes to fuels and chemicals based on fossil feedstock • know different Hydrogen conversion routes to fuels and chemicals based on fossil feedstock • can compare those routes towards the same product based on different feedstock and identify common parts and differences in the processes • evaluate the impact of a transformation from a conventional route to a sustainable route • understand the material cycle of the chemical industry and apply this knowledge into the context of new developments

	• can select suitable technology parts, e.g. type of reactor, for new sustainable routes • understand the interconnection between availability of renewable energy, the supply with Hydrogen and supply with additional feedstock for Power-to-X processes • apply the knowledge in a case study with a Power-to-X process which includes the whole value chain from feedstock supply to production and compare the route to a conventional process • understand and evaluate options for sector coupling, e.g. coupling of steel mills with chemical production

Content	• Overview of Hydrogen conversion processes based on fossil feedstock as well as from renewable feedstock
	  ○ Methanol Synthesis
	  ○ Ammonia Synthesis
	  ○ Methanisation
	  ○ Fischer-Tropsch Synthesis
	  ○ Synthesis of C2-C4 alcohols
	  ○ Biomass conversion to fuels and chemicals
	  ○ H2 in steel production
	• Comparing of conventional routes and sustainable routes, e.g. Power-to-X, for above mentioned processes
	• Overview of the material cycle of fossil feedstocks to fuels and chemicals
	• Evaluation of the impact of the transformation towards sustainable production routes on those material cycles
	• Overview of different sources for all important components of the material cycle
	  ○ CO_2 capture
	  ○ N_2 separation
	• Introduction of economic and sustainability performance indicators
	• Case study on a selected example of a hydrogen conversion process (see “Examination”)

Material	Lecture notes as downloadable files (learning campus)

Examination	The examination is carried out as a Case Study on a selected example of a hydrogen conversion process in a Power-to-X route. In the beginning of the semester the students select a topic and form groups. Based on a defined scope they should work out a report on this case study. This report will be graded.
	
	The case study is embedded in a scenario that such a plant should be built in Burghausen. This implies certain conditions for the power supply and other parts, which should be included in the report. The content of the case study consists of the following points:
	
	• Status Quo:
	  ○ How is “X” produced currently?
	  ○ What is the current global capacity
	  ○ What is the main usage?
	  ○ Draw and describe a flowsheet of the current process from raw material to product
	• New route
	  ○ Select an alternative route for “X”
	  ○ Describe what sustainable raw materials you would select (CO2 from point source or air capture, N2 from air, biomass,…)
	  ○ Draw a flowsheet for the route
	  ○ Calculate a rough mass and energy balance
	  ○ What catalyst is used and how is the catalyst produced
	  ○ Which type of reactor would you chose and why?
	  ○ What is the required land usage for the power supply of your plant? (Select wind/sun or any other renewable source and evaluate the land usage)
	• Compare both routes
	• Include a bibliography with all used sources

Literature	Specific literature for each chapter, current papers, will be announced during lectures

HTS 02: Homogeneous Catalysis

Module Responsible	Prof. Dr. Dominik Pentlehner
Lecturer	Prof. Dr. Dominik Pentlehner
Module Group	Application & Competence-Oriented
Module Duration	1 semester
Term	Winter
Applicability of the module in the degree program	CI 134.2 Homogeneous catalysis; UT 34.2 Homogeneous catalysis
Course Type	• Lecture: 50% • Practical Course: 50%
Credit Points (ECTS)	5
Weekly Working Hours	4
Total Workload	150 hours
Prerequisites	Profound knowledge in Chemistry both theory and practical (lab work)
Number of Participants	Limited (30 in practical course) Enrollment requirements and procedure will be announced via Learning Campus.
Learning Goals	• Overview and knowledge of catalytic methods in chemistry, e.g., heterogeneous, homogeneous, transition metal catalysis or organocatalysis • Understanding of the working principle (reaction mechanism) of homogeneous catalysts • Ability to run experiments under inert atmosphere
Content	• Definitions, advantages and disadvantages compared to other catalytic methods • Reaction mechanisms and experimental setups for homogeneous catalysis • Organometal-chemistry and transition metal catalysis • Organocatalysis • Stereoselective reactions

	• Photocatalysis
Material	Lecture notes as downloadable files (learning campus)
Examination	Admission requirements, type and duration according to Study Regulation (SPO), updated at the beginning of each term, announcements published by the examination office
Literature	Specific literature for each chapter Overview: Breitmaier, E., Jung, G.: Organic Chemistry; Thieme

HTS 03: Energy Politics and Laws

Module Responsible	Prof. Dr.-Ing. Johannes Völkl
Lecturer	NN
Module Group	Application & Competence-Oriented
Module Duration	1 semester
Term	Summer
Applicability of the module in the degree program	Application and competence oriented elective course in HYT-Master
Course Type	• Lecture: 80% • Practical Course: 20%
Credit Points (ECTS)	5
Weekly Working Hours	4
Total Workload	150 hours
Prerequisites	None
Number of Participants	Not limited
Learning Goals	Basic understanding of Energy Politics and Laws with a special focus on Renewable Energy and Hydrogen Technology
Content	• Overview of Energy Politics • Overview of Energy Laws
Material	Lecture notes as downloadable files (learning campus)
Examination	Admission requirements, type and duration according to Study Regulations (SPO), updated at the beginning of each term, announcements published by the examination office
Literature	Specific literature for each chapter, current papers, will be announced during lectures

HTS 04: Advanced Thermodynamics for Hydrogen Applications

Module Responsible	Prof. Dr.-Ing. Johannes Völkl
Lecturer	Prof. Dr.-Ing. Johannes Völkl
Module Group	Specialization
Module Duration	1 semester
Term	Summer
Applicability of the module in the degree program	Specialization elective course in HYT-Master
Course Type	• Lecture: 50% • Practical Course: 50%
Credit Points (ECTS)	5
Weekly Working Hours	4
Total Workload	150 hours
Prerequisites	Fundamental understanding of (chemical) engineering
Number of Participants	Not limited

Learning Goals	After the module students
	• know calculation methods for thermodynamic properties of Hydrogen
	  ○ Ideal Gas Law
	  ○ Soave-Redlich-Kwong
	  ○ Group Contribution Methods
	• can apply those methods to solve technical problems in e.g. compression, combustion or separation
	• identify, when to use more sophisticated thermodynamic models instead of ideal equations
	• know how to calculate combustion characteristics:
	  ○ Flame speed
	  ○ Flame length
	  ○ Combustion temperature
	  ○ Flue gas composition

	• know the difference in combustion characteristics between Hydrogen and hydrocarbons • know the influence of these differences on flame characteristics and combustion design • evaluate the influence of these differences on the design of combustion chambers and combustion engines • evaluate if hydrogen combustion is technological and economical feasible

Content	• Overview of thermodynamic cycle processes
	• Property methods for hydrogen
	• General combustion theory
	  ○ Combustion temperature
	  ○ Flame characteristics
	  ○ Burner design
	• Comparison of hydrogen combustion with hydrocarbon combustion
	  ○ Estimation of combustion temperature
	  ○ Estimation of flue gas composition
	  ○ Estimation of energy release
	• Internal combustion engines with Hydrogen for transportation
	• Thermodynamics of Hydrogen compression

Material	Lecture notes as downloadable files (learning campus)

HTS 05: Sources and Generation of Hydrogen

Module Responsible	Prof. Dr.-Ing. Patrick Preuster
Lecturer	Prof. Dr.-Ing. Patrick Preuster
Module Group	Specialization
Module Duration	1 semester
Term	Summer
Applicability of the module in the degree program	Specialization elective course in HYT-Master
Course Type	• Lecture: 50% • Practical Course: 50%
Credit Points (ECTS)	5
Weekly Working Hours	4
Total Workload	150 hours
Prerequisites	Fundamental understanding of (chemical) engineering
Number of Participants	Not limited
Learning Goals	After the course students • know the different routes for hydrogen generation processes in depth • understand the advantages and disadvantages of each process route • are able to calculate mass- and energy balances for hydrogen generation processes • are able to select a suitable hydrogen generation process for a given downstream process based on different parameters • know the environmental impact of the different hydrogen generation process e.g. global warming potential
Content	• Overview of Hydrogen generation processes • Process routes of conventional Hydrogen production processes

	• Process routes of sustainable Hydrogen production processes • Comparing different electrochemical water splitting technologies • Comparison of Hydrogen generation processes
Material	Lecture notes as downloadable files (learning campus)
Examination	Admission requirements, type and duration according to Study Regulation (SPO), updated at the beginning of each term, announcements published by the examination office
Literature	Specific literature for each chapter, current papers, will be announced during lectures

HTS 06: Hydrogen Storage, Transportation and Distribution Systems

Module Responsible	Prof. Dr.-Ing. Patrick Preuster
Lecturer	Prof. Dr.-Ing. Patrick Preuster
Module Group	Specialization
Module Duration	1 semester
Term	Winter
Applicability of the module in the degree program	Specialization elective course in HYT-Master
Course Type	• Lecture: 70% • Practical Course: 30%
Credit Points (ECTS)	5
Weekly Working Hours	4
Total Workload	150 hours
Prerequisites	Fundamental understanding of (chemical) engineering
Number of Participants	Not limited
Learning Goals	After the course students • know the different methods for hydrogen storage • understand the advantages and disadvantages of each storage technology • are able to calculate mass- and energy balances for hydrogen storage methods • are able to calculate specific hydrogen storage and transportation costs for different technologies • are able to compare hydrogen storage technologies • are able to select a suitable hydrogen storage and transportation method know the environmental impact of the different hydrogen generation process e.g. global warming potential
Content	• Overview of Hydrogen storage and transport methods from a distribution and transportation point of view

	◦ Ammonia ◦ Liquid hydrogen ◦ Gaseous hydrogen ◦ Ethers ◦ Acids ◦ Alcohols ◦ Liquid Organic Hydrogen Carriers ◦ Metal Hydrides ◦ Adsorption • Detailed discussion of selected storage methods • Detailed discussion of selected transport and distribution methods • Comparison of different methods to store and transport Hydrogen
Material	Lecture notes as downloadable files (learning campus)
Examination	Admission requirements, type and duration according to Study Regulation (SPO), updated at the beginning of each term, announcements published by the examination office
Literature	Specific literature for each chapter, current papers, will be announced during lectures

HTS 07: Electrochemical Process Engineering

Module Responsible	Prof. Dr.-Ing. Patrick Preuster
Lecturer	Prof. Dr.-Ing. Patrick Preuster
Module Group	Specialization
Module Duration	1 semester
Term	Summer
Applicability of the module in the degree program	Specialization elective course in HYT-Master
Course Type	• Lecture: 75% • Practical Course: 25%
Credit Points (ECTS)	5
Weekly Working Hours	4
Total Workload	150 hours
Prerequisites	Fundamental understanding of (chemical) engineering
Number of Participants	Not limited
Learning Goals	After the course students • understand electrochemical conversion processes • understand electrochemical catalysis • know different processes for electrochemical hydrogen generation as well as consumption • understand the concept of Co-electrolysis and are able to design a suitable process integration • are able to compare electrochemical process routes • are able to select suitable electrochemical conversion units for given process conditions apply the knowledge in a case study
Content	• Overview of electrochemical fundamentals • Overview of electrochemical process concept • Definitions of fundamental concepts in electrochemical processes

	• Water Electrolysis and Fuel Cell Application • Electrochemical CO_2 Reduction • Reactor and Process Concepts
Material	Lecture notes as downloadable files (learning campus)
Examination	The examination is carried out as a Case Study on a selected example for which an electrochemical process should be carried design and scaled appropriately. Admission requirements, type and duration according to Study Regulation (SPO), updated at the beginning of each term, announcements published by the examination office
Literature	Specific literature for each chapter, current papers, will be announced during lectures

HTS 08: Techno-Economic Analysis and Simulation

Module Responsible	Prof. Dr.-Ing. Johannes Völkl
Lecturer	Prof. Dr.-Ing. Johannes Völkl
Module Group	Application & Competence-Oriented
Module Duration	1 semester
Term	Summer
Applicability of the module in the degree program	MF 43 Techno-Economic Analysis and Simulation
Course Type	• Lecture: 50% • Practical Course: 50%
Credit Points (ECTS)	5
Weekly Working Hours	4
Total Workload	150 hours
Prerequisites	Fundamental understanding of (chemical) engineering
Number of Participants	Not limited
Learning Goals	After the module the students • know the parts of a Techno-Economic Analysis • understand how to obtain required data for Techno-Economic Analysis • can compare different approaches to estimate CAPEX based on characteristic process data • know factors to quantify sustainability criteria of process routes • apply the learned concepts in an individual case study in which a Techno-Economic calculation is carried out • can use ASPEN Plus in the context of Techno-Economic Analysis
Content	• Fundamentals of economical process assessment • Calculation of CAPEX and OPEX for process routes • Evaluation of different CAPEX estimation approaches

	• Application of evaluation methods for sustainability criteria, e.g. greenhouse gas emissions • Overview of methods of conceptual process design • Comparison of different approaches for a Techno-Economic evaluation of process routes • Individual Case Study: Techno-Economic evaluation for a selected topic as examination project • Introduction to the usage of Process Simulation to generate data for Techno-Economic Analysis
Material	Lecture notes as downloadable files (learning campus)
Examination	The examination is carried out as a Case Study on a selected example for which a Techno-Economic evaluation should be carried out. The process set-up will be given, the students should apply the different methods for CAPEX and OPEX calculations they learned in the lecture. The required content for the report and the specific project topics are announced in the beginning of the semester in the lecture and Learning Campus.
Literature	Specific literature for each chapter, current papers, will be announced during lectures

HTS 09: Energy Technologies

Module Responsible	Prof. Dr.-Ing. Patrick Preuster
Lecturer	Prof. Dr.-Ing. Patrick Preuster
Module Group	Application & Competence-Oriented
Module Duration	1 semester
Term	Winter
Applicability of the module in the degree program	
Course Type	• Lecture: 80% • Practical Course: 20%

Credit Points (ECTS)	5
Weekly Working Hours	4
Total Workload	150 hours
Prerequisites	Fundamental understanding of (chemical) engineering
Number of Participants	Not limited
Learning Goals	After the module the students • know basic terms of the energy industry • know the impact of power generation on environment and climate • are able to explain the functioning and areas of application of the various technologies for power and heat generation, distribution and storage technologies • are able to demonstrate the links between energy generation and climate change • are able to identify key factors in the pricing of electricity, gas and heat • are able to make comparative assessments of the environmental impact of different technologies of energy generation • are able to carry out simple material/energy flow calculations for energy generation plants • are able to carrying out simple economic efficiency calculations for energy generation plants
Content	• Basic concepts of the energy industry • Reserves and resources of conventional energy sources • Statistics and forecasts of energy production and consumption • Energy and climate, energy policy programs • Thermal power generation (coal, gas, biogas, nuclear power plants, geothermal, solar thermal power plants) • Non-thermal power generation (hydropower, wind power, photovoltaics) • Electricity distribution and storage

Material	Lecture notes as downloadable files (learning campus)
Examination	The examination is carried out as a Case Study on a selected example for which an conventional and a renewable energy production or storage method should be compared regarding certain KPIs e.g. GHP. Admission requirements, type and duration according to Study Regulation (SPO), updated at the beginning of each term, announcements published by the examination office
Literature	Specific literature for each chapter, current papers, will be announced during lectures

HTS 10: Introduction to the Economics of Hydrogen Markets

Module Responsible	Prof. Dr. Jan Lüken
Lecturer	Prof. Dr. Jan Lüken
Module Group	Application & Competence-Oriented
Module Duration	1 semester
Term	Summer
Applicability of the module in the degree program	
Course Type	• Lecture: 50% • Practical Course: 50%
Credit Points (ECTS)	5
Weekly Working Hours	4
Total Workload	150 hours
Prerequisites	none
Number of Participants	Not limited
Learning Goals	Upon completion of this course, students will be able to: • Articulate the economic, social, and environmental underpinnings of the hydrogen economy. • Analyze the challenges and opportunities of hydrogen in an economic context, especially regarding the green transformation in Germany and Europe. • Evaluate the role of policy and regulation in shaping the hydrogen market and its integration into existing energy systems. • Develop informed perspectives on the future of hydrogen as a key component of global energy transitions.
Content	• Economic Evaluation: Apply economic principles and models to assess the feasibility, sustainability, and market potential of hydrogen technologies and initiatives. This includes understanding cost structures, pricing mechanisms, and financial incentives.

	• Policy and Regulatory Insight: Analyze the impact of policy and regulation on the hydrogen economy, identifying how governmental frameworks can support or hinder economic viability and market development. • Market Analysis: Understand the dynamics of the hydrogen market, including supply and demand factors, market segmentation, and the role of international trade in hydrogen economics. • Strategic Thinking and Business Modelling: Formulate strategies to navigate economic and regulatory barriers in the development of the hydrogen economy, with an emphasis on identifying economic opportunities and creating value in emerging hydrogen markets.
Material	Lecture notes as downloadable files (learning campus)
Examination	Admission requirements, type and duration according to Study Regulation (SPO), updated at the beginning of each term, announcements published by the examination office
Literature	Specific literature for each chapter - Heuser, P. M., Ryberg, D. S., Grube, T., Robinius, M., & Stolten, D. (2019). Techno-economic analysis of a potential energy trading link between Patagonia and Japan based on CO2 free hydrogen. *International journal of hydrogen energy*, *44*(25), 12733-12747 - Schippert, J., Runge, P., Farhang-Damghani, N., & Grimm, V. (2022). Greenhouse gas footprint of blue hydrogen with different production technologies and logistics options. *Available at SSRN 4153724*. - Robinius, M., Cerniauskas, S., Madlener, R., Kockel, C., Praktiknjo, A., & Stolten, D. (2022). Economics of Hydrogen. In The Palgrave Handbook of International Energy Economics (pp. 75-102). Cham: Springer International Publishing.

HTS 11: Computational Fluid Dynamics for Process Industry

Module Responsible	**Prof. Dr.-Ing. Johannes Lindner**
Lecturer	Prof. Dr.-Ing. Johannes Lindner
Module Group	Specialization
Module Duration	1 semester
Term	Winter
Applicability of the module in the degree program	Specialization elective course in HYT-Master
Course Type	• Lecture: 50% • Practical Course: 50%
Credit Points (ECTS)	5
Weekly Working Hours	4
Total Workload	150 hours
Prerequisites	Fundamental understanding of (chemical) engineering including basics in mathematics and fluid mechanics
Number of Participants	Limited (30) Enrollment requirements and procedure will be announced via Learning Campus.
Learning Goals	After the course students • understand the limitations of CFD • know the basics of computational fluid dynamics • can design, model and mesh • can simulate flow of gas and reactions including gas • can apply CFD to applications in hydrogen technology
Content	• Introduction and overview of simulation approaches • Overview of computational fluid dynamics • Finite Volumes Meshing • Navier-Stokes-equations for CFD • Numerical solving of equations • Evaluation and presentation of simulation results

	• Short introduction to selected other simulation methods
Material	Lecture notes as downloadable files (learning campus)
Examination	The students create a project study thesis on a individual CFD-simulation of a process linked to hydrogen technology. Admission requirements, type and duration according to Study Regulation (SPO), updated at the beginning of each term, announcements published by the examination office
Literature	Specific literature for each chapter, current papers, will be announced during lectures

HTS 12: Membrane Technologies

Module Responsible	**Prof. Dr.-Ing. Angela Klüpfel**
Lecturer	Prof. Dr.-Ing. Angela Klüpfel
Module Group	Specialization
Module Duration	1 semester
Term	Winter
Applicability of the module in the degree program	Specialization elective course in HYT-Master
Course Type	• Lecture: 75% • Practical Course: 25%
Credit Points (ECTS)	5
Weekly Working Hours	4
Total Workload	150 hours
Prerequisites	Chemistry and (chemical) engineering fundamentals, including (chemical) lab work experience
Number of Participants	Limited (16) Enrollment requirements and procedure will be announced via Learning Campus.
Learning Goals	After the course students

	• Understand fundamentals of mass transport, advantages and limitations of membrane processes in different applications • Can discuss recent developments in membrane materials and membrane processes supporting emission control, circularity, resource efficiency, and hydrogen applications • Can plan and perform basic screening experiments for a given separation challenge • Can roughly design a membrane based process combination by assessment of starting point and objective, derivation of pretreatment requirements, evaluation of experimental results and estimation of process parameters • Can apply membrane technologies to applications in hydrogen technology
Content	• Overview on membrane applications • Membrane technology fundamentals (driving forces, mass transport, materials, preparation) • Membrane modules, process design and operation • Characterization methods • Recent developments and case studies • Membrane based applications discussed in the course will include e.g.: water and waste water treatment, resource recovery, industrial liquid and gas separation processes, fuel cells and electrolysis • The practical part consists of a case study in the field of membrane applications in aqueous environments which includes literature search, lab experiments and process design.
Material	Lecture notes as downloadable files (learning campus)
Examination	Admission requirements, type and duration according to Study Regulation (SPO), updated at the beginning of each term, announcements published by the examination office

Literature	Specific literature for each chapter, current papers, will be announced during lectures

HTS 13: Heterogenous Catalysis

Module Responsible	**Prof. Dr. Dorottya Kriechbaumer**
Lecturer	Prof. Dr. Dorottya Kriechbaumer
Module Group	Application & Competence-Oriented
Module Duration	1 semester
Term	Winter
Applicability of the module in the degree program	Application & Competence-Oriented elective course in HYT-Master
Course Type	• Lecture: 75% • Practical Course: 25%
Credit Points (ECTS)	5
Weekly Working Hours	4
Total Workload	150 hours
Prerequisites	Profound knowledge in chemistry (thermodynamics, reaction kinetics), practical experience in laboratory work
Number of Participants	Unlimited In WS 23/24: Optional lab course, group size and group organization will be announced in the lecture
Learning Goals	The students gain an: • Overview of heterogeneous catalysis and relevance in the chemical industry • Understanding the kinetics of heterogeneous catalysis • Understanding the design, preparation and characterization methods of catalysts • Insight into the process engineering of heterogeneous catalysis and typical reactors

	• Insight to application for power-to-hydrogen, and hydrogen-to-power solutions
Content	• Definition, fundamentals and comparison to other catalytic methods • Surface reactions • Reaction kinetics, reaction mechanism • Types of catalysts • Catalyst preparation, characterization and degradation • Life cycle of a catalyst • Catalytic process engineering • Introduction of electrocatalysis and photocatalysis
Material	Lecture notes as downloadable files (learning campus)
Examination	Admission requirements, type and duration according to Study Regulation (SPO), updated at the beginning of each term, announcements published by the examination office
Literature	Specific literature for each chapter, current papers, will be announced during lectures