Hanzehogeschool Groningen
University of Applied Sciences

European Master in Renewable Energy (MSc)

Short Module Descriptions Handbook
Specialisation semester SFS 2024-2025

share your talent. move the world.

Table of Contents

1. Short Module Descriptions Handbook

1.1. Introduction

Within the European Master Renewable Energy (EMRE) programme, the student can choose her/his specialization. One of the specializations, Specialisation Sustainable Fuel Systems, is offered at the Hanze University of Applied Sciences.

This specialisation semester is designed such that students will acquire a systemic view on sustainable fuel supply chains, *i.e.* students will not only learn about fuel production technologies and the physics on which these are based, but will also learn how technologies contribute to energy systems, including energy storage. If you want to contribute to a more sustainable transport sector this will be the right specialisation: from science to practice. This approach is effectuated in the following modules:

- **Physics and Fuels**. In this module we focus on thermodynamics, properties of fuels, and transport and storage processes, *eg.* liquefaction, compression.
- **Bio-energy Conversion**. This module gives a broad understanding of the various biochemical and thermochemical conversion processes involved in the conversion of biomass into biofuels. The making of renewable fuels (biofuels) is addressed, *eg.* biomethane, bioethanol, biohydrogen, biodiesel. Basic biochemistry, gasification, pyrolysis are examples of processes discussed. The module includes modelling, lab work, and reactor design. This module is executed in cooperation with the Dutch research centre ECN-TNO.
- **Power-to-Hydrogen**. Students will learn principles and operation of electrolysers and fuel cells. Basic electrochemistry, electrolyser types, and parameters which influence the operation of electrolysers and fuel cells are covered. The technology is compared to electrochemical storage (batteries).
- **Sustainable Fuel System Design**. In this module students learn to develop a systemic vision on technologies in energy systems and learn how to build a technoeconomic-environmental model and a linear programming (LP) model in MATLAB. Sustainability, supply chain energy efficiencies, and greenhouse gas emission saving are key topics addressed.
- **New Business Development**. In this module the business opportunities of biofuels and hydrogen are investigated. You will learn an analytical way of thinking about introducing of new technologies and products into the market and pitch you plan to stakeholders.

The modules are supported by several excursions to innovative projects/companies. More detailed module descriptions can be found in the Course catalogue

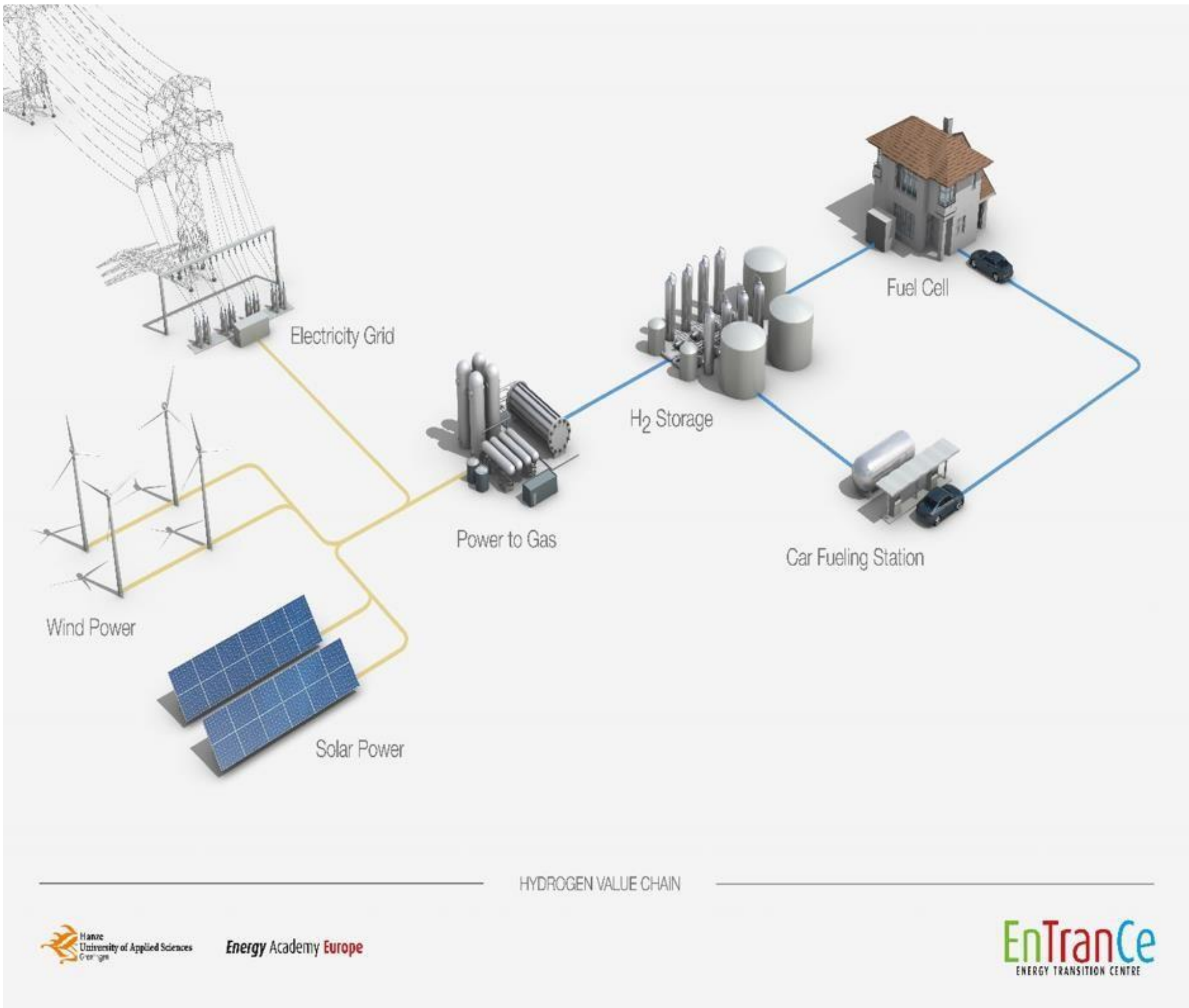

Figure 1: Hydrogen value chain as investigated in the various modules of this specialisation.

The next chapters provide a short module description of all modules.

2. Specialisation Sustainable Fuel Systems – Hanze UAS

2.1. Physics and Fuels (RWVM23PAF)

Institute for Engineering **Subject:** *European MSc in Renewable Energy* *Summer Term*	**Category:** - *MSc Module* **Degree award:** - *MSc*
Emphases: -	**Sections:** -
Module reference number/Title: *Physics and Fuels*	
Duration: 3 weeks **Cycle:** once a year **Type of module:** mandatory **Level:** MM (MSc module) *This module should be taken in 2nd semester*	**Type of program:** Lecture, Laboratory, Excursion **Language:** English **Attainable credit points:** 5 EC **Workload:** 140 hours **Required attendance:** 50 hours
Person responsible for the program: C.B. Vogt, PhD	**Person responsible for this module:** Dr A. Perl
Alternative person(s) responsible for this module: Dr. V. Parthasarathy	**Examiner(s):** Dr V. Parthasarathy Dr A. Perl

Objective of the module / skills:
By completing the module the student demonstrates knowledge and understanding of:
E2.1.c.1 states of matter and state transfer
E2.1.c.2 combustion, heat transfer and fluid mechanics
E2.2.a.1 gaseous energy carriers: hydrogen, biogas, green gas, CNG, CBG
E2.2.a.2 liquid energy carriers: gas-to-liquid, ethanol, liquefied hydrogen, LNG
E2.2.c.1 storage: parameters and technologies

And is able to:
E2.4.a.1 model processes for fuel production with a focus on downstream
E1.1.c.1 present an overview of the processes

Content of the module:
Theory (4 EC):
- ideal vs real gas, equations of state, compressibility
- heat transfer
- cryogenics (Joule-Thomson)
- combustion technology (incl. engines and emissions)
- fuels (properties/flow/storage)
- additives
- compression
- storage

Lab (1 EC):
- Aspen Plus

Mandatory literature
- Perl A, Reader, 2019 (available on Blackboard)
- Çengel, Y. A. & Boles, M. A. Thermodynamics: an engineering approach. (McGraw-Hill Education, 2015)
- Bekkering J, Readers, 2018 (available on Blackboard)

Comments:
-

Weblink:
-

Prerequisites for admission:
-

Helpful previous knowledge:
-

Associated with the module(s):
-

Maximum number of students / selection criteria:

-

Types of examinations:

Report (4 EC)

Lab Report (1 EC)

Examination periods:

Feb-March

Registration procedure: OSIRIS: RWVM23PAF

2.2. Bio Energy Conversion (RWVM23BEC)

Institute for Engineering **Subject:** *European MSc in Renewable Energy Summer Term*	**Category:** - *MSc Module* **Degree award:** - *MSc*
Emphases: -	**Sections:** -
Module reference number/Title: *Biochemical & Thermochemical Conversion*	
Duration: 7 weeks **Cycle:** once a year **Type of module:** mandatory **Level:** MM (MSc module) *This module should be taken in 2nd semester*	**Type of program:** Lecture, Laboratory, Excursion, Tutorial **Language:** English **Attainable credit points:** 10 EC **Workload:** 280 hours **Required attendance:** 96 hours
Person responsible for the program: C.B. Vogt, PhD	**Person responsible for this module:** Dr. A. Perl
Alternative person(s) responsible for this module: F. Pasquini, MSc, Dr. M. Cieplik (ECN/TNO), dr. F. Faber	**Examiner(s):** All listed Persons

Objective of the module / skills:
To have demonstrated knowledge and understanding of:

- Chemistry to calculate the thermodynamic outcome of various (bio)chemical reactions
- Thermodynamic and kinetic basics of different biochemical and thermochemical conversion technologies
- Broad variety of (lignocellulosic) biomass feedstocks and energy carriers, based on their origin (woody/non-woody), chemical composition as well as physical properties
- Distinguishing the many choices in biological and thermochemical conversion processes
- The practical challenges of various biochemical conversion technologies (fermentation/digestion) and based on various technical designs (batch/continuous), including general characteristics and sub-processes
- The practical challenges of various thermochemical conversion technologies (pyrolysis/gasification/combustion) and based on various technical designs (fixed/fluidized bed/pulverized fuel), including general characteristics in terms of scales, emissions and system efficiencies
- Unit operations that are required for a given biochemical and thermochemical process - Environmental score/impact of producing biofuels

To be able to

- Make mass and energy balances in biological and thermochemical conversion processes;
- Set up a biological conversion experiment (e.g. anaerobic digestion or photo-bioreactors);
- Design a biofuel plant including the streams, processes and stakeholders;
- Model a biofuel production plant and calculate energy conversion efficiencies;
- Recognize different types of biomass feedstock and upgraded biomass energy carriers;
- Select a suitable thermochemical conversion process, based on biomass/feedstock chemical composition and physical properties;
- Contribute to discussions with experts;
- Demonstrate knowledge of the various types of biofuels and their capabilities/suitability to particular mobility applications and engines;
- Demonstrate understanding of end-use specifications (including purity, storage) for biofuels and how these relate to the processing of the biofuels from raw materials;
- Perform material and energy balances over sub-processes and processes involved in a bio-refinery using Aspen Plus;
- Model a biofuel production plant using Aspen Plus and calculate energy conversion efficiencies (and other relevant factors);
- Evaluate the business case of a modeled production facility which meets appropriate specifications for the product;

Content of the module:

Biochemical Conversion:

Chemical and physical bonds, chemical groups, biomolecules, biopolymers, enzymes and their reactions

Organisms, cell structures, genetics, metabolism, catabolism, anabolism, cycles, photosynthesis, carbon cycle

Reaction order and rate, reactor types, steady state, mass and energy balances for various reactor types

Physical and chemical properties of various biomaterials, overview of biochemical conversion routes, chemical content, main structural chemical constituents

Biomass cultivation, harvesting, collection, and supply chain management, biomass pretreatment technologies, downstream processing, separation

1st generation biofuels

What defines it. Which type of biofuels it produces. Advantages and disadvantages of this

generation. The pretreatments required for the most used biomass type.
Differences between the two main producers of bioethanol: EUA and Brazil. The story of bioethanol in Brazil: from when it started, shortages, price, production, evolving techniques
2^{nd} generation biofuels
Types of fuels. A real case of 2nd generation biofuel production: the processes to produce biofuels, effect of operating conditions on chemical composition, heating value and yield of biogas, biochar and bio-oil
3^{rd} and 4^{th} generation biofuels
Types of processes and fuels. Enzymes used to modify microorganisms. The barriers it overcome, and its concept. New problems that comes with it. Lifecycle analysis (LCA) and consolidated bioprocessing
The importance of LCA. The steps of LCA for biofuels (raw material production, transportation, manufacturing, storage..) Sustainability of biofuels: The social, economic and environmental performance of the renewable energy source. What determines which biofuel generation is more suitable for each case.
The innovative approach of consolidated bioprocessing. Advantages and disadvantages. CBP and pretreatments processes. Case studies

Thermochemical conversion:
Basic properties of biomass feedstocks- and -derived energy carriers
- Organic and inorganic compositions of raw and mechanically/thermally upgraded lignocellulosic biomass
- Physical properties of raw and mechanically/thermally upgraded lignocellulosic biomass energy carriers
- Suitability of different biomass types for specific thermochemical processes Basics of thermochemical conversion processes:
- Torrefaction ○ dry/wet
- Pyrolysis
    - fast/slow
- Gasification ○ direct/indirect
    - producer gas purification and upgrading to various qualities
- Combustion ○ direct/air-staged
    - for heat and/or power generation
- Typical temperature levels, scales and overall mass/energy efficiencies
- Compositions of typical flue-, process- and producer-gasses, including by-products, impurities and emissions
- Specific technology solutions for pyrolysis, gasification and combustion:
- Grate-fired/fixed/moving bed systems
- Fluidised-bed systems
- Pulverised-fuel systems
- Typical technical bottlenecks and solutions to overcome those for each specific technology solution
- The technological maturity and the role in the current and (potential) future heat and power market.

Aspen Programming Topics
- Introduction to bio refinery
- Aspen computer Lab unit operations (1), utilities & coupling Unit Ops (2), closing loops & optimization (3,4), business case tutorial(5)

Suggested reading: • W de Jong & JR van Ommen (Eds.), "Biomass as a sustainable energy source for the future", Hoboken, NJ, USA: Wiley & Sons, Inc.(2014) • Further reading material to be announced at the beginning of the lecture period

Comments: - **Weblink:** - **Prerequisites for admission**: -	**Helpful previous knowledge:** - **Associated with the module(s):** -

Maximum number of students / selection criteria: - **Types of examinations:** • Biochemical Conversion Report (3 EC) • Thermochemical Conversion Report (5 EC) • Lab Biofuels (BioEthanol making) Lab Report (2 EC) **Examination periods:** - May/April **Registration procedure:** OSIRIS: RWVM23BEC

2.3. Power2Hydrogen (RWVM23P2U)

Institute for Engineering **Subject:** *European MSc in Renewable Energy* *Summer Term*	**Category:** - *MSc Module* **Degree award:** - *MSc*
Emphases: -	**Sections:** -
Module reference number/Title: *Power2Hydrogen (P2H)*	

Duration: 3 weeks **Cycle:** once a year **Type of module:** mandatory **Level:** MM (MSc module) *This module should be taken in 2nd semester*	**Type of program:** Lecture, Laboratory, Tutorials **Language:** English **Attainable credit points:** 5 EC **Workload:** 140 hours **Required attendance:** 50 hours
Person responsible for the program: C.B. Vogt, PhD	**Person responsible for this module:** Dr. A. Perl
Alternative person(s) responsible for this module:	**Examiner(s):** Dr. A. Perl Dr V. Parthasarathy
Objective of the module / skills: By completing the module the student demonstrates knowledge and understanding of: *E2.2.a.1 theoretical constructs and scientific frameworks relevant to power-to-hydrogen* *E2.2.a.2 main sources of energy dissipation in electrolysers and fuel cells* *E2.2.b.1 power-to-hydrogen value chains for mobility* And is able to: *E2.1.c.1 design scientific experiments to analyse the performance of electrolysers and fuel cells* *E2.3.e.1 define and measure the energy efficiency of electrolysers and fuels cells* *E1.1.c.1 archive and communicate effectively experimental results*	

Content of the module:

Theory (3 EC):
- Electrochemistry basics
- Electrochemical storage - overview on electrochemical storage, including fundamentals of batteries and fuel cells. Limits and applications
- Electrolysis: theory and electrolyser design
- Fuel cells: theory and design

Experiments (2 EC):
- Electrolyser and fuel cell measurements
- Adsorption (storage) measurements

Suggested reading:
- Godula-Jopek A, Hydrogen production by electrolysis, Wiley-VCH, Weinheim Germany, 2015 (e-book available in Hanze library)
- Revankar S, Majumdar P, Fuel Cells – Principles, Design and Analysis, CRC Press, ISBN 9781420089684, 2014 (hard copy available in Hanze library)
- Fardo SW, Dale PR., *Industrial Process Control Systems*, 2nd Edition, The Fairmont Press, 2009 (ebook in the library available)

Comments:

-

Weblink:

-

Prerequisites for admission*:*

-

Helpful previous knowledge:

-

Associated with the module(s):

-

Maximum number of students / selection criteria:

-

Types of examinations:
- Assignment 1; Report (3 EC)
- Assignment 2; Report (2 EC)

Examination periods:
- March

Registration procedure:

OSIRIS: RWVM23P2U

2.4. Sustainable Fuel System Design (RWVM23SFSD)

<table>
<tr><td>Institute for Engineering
Subject: European MSc in Renewable Energy
Summer Term</td><td>Category:
- MSc Module
Degree award:
- MSc</td></tr>
<tr><td>Emphases:
-</td><td>Sections:
-</td></tr>
<tr><td colspan="2">Module reference number/Title:
Sustainable Fuel System Design (SFD)</td></tr>
<tr><td>Duration: 1 semester
Cycle: once a year
Type of module: mandatory
Level: MM (MSc module)
This module should be taken in 2nd semester</td><td>Type of program:
Lecture, Laboratory, Tutorials Language:
English
Attainable credit points: 5
EC
Workload:
140 hours
Required attendance: 50
hours</td></tr>
<tr><td>Person responsible for the program:
C.B. Vogt, PhD</td><td>Person responsible for this module:
Dr. ir. J. Bekkering</td></tr>
<tr><td>Alternative person(s) responsible for this module:
Dr. E.J. Hengeveld</td><td>Examiner(s):
Dr. ir. J. Bekkering
Dr. E.J. Hengeveld</td></tr>
<tr><td colspan="2">Objective of the module / skills:

By completing the module the student demonstrates knowledge and understanding of:
E2.1.a.1. problem definition in supply chain analysis
E2.1.b.1 critical analysis of relevant literature and empirical background materials</td></tr>
</table>

And is able to:

E2.3.a.1	*formulate models of energy systems, using methods and techniques for energy systems*
E2.3.d.1	*select an appropriate technique for modelling given energy problems, such as Linear Programming (LP) and Mixed Integer Linear Programming techniques (MILP)*
E2.3.d.2	*explain the underlying assumptions and limitations*
E2.4.a.1	*implement these models*
E1.1.c.1	*systematic report research question, methods, results, discussion and conclusions*

Content of the module:

- Supply chain concepts: Material Flow Analysis, Life Cycle Cost of Energy
- Sustainability: concepts, Primary Energy Input Output Ratio, greenhouse gas emission saving, well-to-wheel analysis (WTT, TTW, WTW)
- Theory on LP, MILP, sensitivity analysis, Monte Carlo
- MATLAB modeling

Suggested reading:

- Bekkering, Readers, 2016 (available on Blackboard)
- Bekkering J, Hengeveld EJ, Gemert WJT van, Broekhuis AA, *Will implementation of green gas into the gas supply be feasible in the future?*, Applied Energy 2015, 140: 409-417
- Montoya J, Hengeveld EJ, Reader, 2019 (available on Blackboard)
- Hu TC, Kahng AB, *Linear and Integer Programming Made Easy*, Springer, 2016, ISBN 978-3-319-24001-5 (e-book available in Hanze library)

Comments:

-

Weblink:

-

Prerequisites for admission*:*

-

Helpful previous knowledge:

-

Associated with the module(s):

-

Maximum number of students / selection criteria:

-

Types of examinations:

- Assignment 1 (2 EC) : Sustainable supply chains (report)
- Assignment 2 (3 EC) : LP (report)

Examination periods:

- April

Registration procedure:

OSIRIS: RWVM23SFSD

2.5. New Business Development (RWVM23NBD)

Institute for Engineering **Subject:** *European MSc in Renewable Energy* *Summer Term*	**Category:** - *MSc Module* **Degree award:** - *MSc*
Emphases: -	**Sections:** -
Module reference number/Title: *New Business Development*	
Duration: 1 semester **Cycle:** once a year **Type of module:** mandatory **Level:** MM (MSc module) *This module should be taken in 2nd semester*	**Type of program:** Lecture, Laboratory, Excursion, Tutorials **Language:** English **Attainable credit points:** 5 EC **Workload:** 140 hours **Required attendance:** 50 hours
Person responsible for the program: C.B. Vogt, PhD	**Person responsible for this module:** Dr. ir. JJ. Aué
Alternative person(s) responsible for this module: Dr. ir. M. van Steenis	**Examiner(s):** Dr. ir. JJ. Aué Dr. ir. M. van Steenis
Objective of the module / skills: To be able to: 1. Judge the technical feasibility of bio-fuel facilities 2. Assess the sustainability of the process To have demonstrated knowledge and understanding of: • Bio- fuel concepts • Business model canvas / business cases • Life cycle analysis • Developing new value chains To be able • Writing and pitching a business plan	

Content of the module:
Different sustainable fuel systems can be developed, each with its own characteristics and thus its own market, depending on the requirements that certain consumer segments will have.
In this module we will study two sustainable fuels systems based on gaseous sustainable fuels: bioLNG and hydrogen. Reference systems can for example be electric or fossil fuel based transport.
The final goal of this module is to investigate and present one of these sustainable fuel systems in the form of a business concept, including advantages and disadvantages when compared to other fuel systems.
To be able to develop such a concept, the following program has been developed:
1. Introduction on business models and recap LCA - Chain analysis: o
Chain efficiency
o SCBA
o Financial analysis - Stakeholder involvement
- Business Models
2. Introduction on two sustainable fuel chains
- Bio LNG
- Hydrogen
3. Value chain new business development
4. Business tools
- Business Model Canvas
- Financial parameters (ROI, NVP, CAPEX, OPEX)
- Partner analysis
- Competition analysis
5. Business development plan based on the tool from point 2 and 3 for one of the cases presented
6. Presentation and defense of own concepts based on one of the cases presented
- Pitch (who, what, how , why)
- Consultative selling technique SPIN
- Pyramid principle reasoning

Suggested reading:
Starting out on social return of investment:
http://www.socialvalueuk.org/app/uploads/2016/03/Starting%20Out%20Guide.pdf. Maus, 2013. Sustainable fuel – Fantasy. Cover story Innovation & Sustainability.
Autotechreview.com

- Borne, 2015. Explore policies to stimulate Bio LNG using a social cost benefit analysis.
- Betralmello et al, 2013. Why New business models matter for green growth
- Bolat et al, 2014 , Hydrogen supply chain architecture for bottom-up energy systems models.

Part 1 and 2 : Developing pathways wulf et al , 2018 , life cycle assessment hydrogen transport and distribution
Bhandari et al, 2014 , lca hydrogen production review.

Technology Roadmap , Hydrogen and Fuel Cell (and annex) IEA 2015Element Energy , 2018, Hydrogen Supply Chain Overview
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/
760479/H2_supply_chain_evidence_-_publication_version.pdf
Sebastian Schiebahn a.o., , 2015 Power to Gas: Technological overview, systems analysis and economic assessment for a case study in Germany.
Tractebel and Hinicio , 2017, study on early business cases for h2 in energy storage and more broadly power to h2 applications final report, FCH-JU by Well-to-wheel analysis for electric, diesel and hydrogen traction for railways , Andreas Hoffrichter a,⇑ , Arnold R. Miller b , Stuart Hillmansen a , Clive Roberts a ○ Dai et al, 2015. Gasification of Woody Biomass. ○ Zhang et al, 2018. Life cycle assessment and optimization analysis of different LNG usage scenarios.
○ Kumar et al, 2015. LNG: An eco-friendly cryogenic fuel for sustainable development.
○ Moreno – Benito et al, 2014 , Towards a sustainable hydrogen economy: Optimisation-based framework for hydrogen infrastructure development

Business makeover website http://www.businessmakeover.eu Barbara Minto, the pyramid principle (Hanze Library or online).
ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects, ENTSOE, 2018 Guide to Cost-Benefit Analysis of Investment Projects, European union, 2015
Lazard levelized cost of energy 2018
Tantau et al , 2018, Business Models for Renewable Energy Initiatives : Emerging Research and Opportunities.
http://search.ebscohost.com.nlhhg.idm.oclc.org/login.aspx?direct=true&db=nlebk&AN=1559769&si
te=ehost-live
Future cost and performance of water electrolysis: An expert elicitation study O. Schmidt a,b,*, A. Gambhir a, I. Staffell b, A. Hawkes c, J. Nelson a, S. Few a

Comments: - **Weblink:** - **Prerequisites for admission**: -	**Helpful previous knowledge:** - **Associated with the module(s):** -

Maximum number of students / selection criteria:

-

Types of examinations:

Item	Group / Individual	Activity	Items graded	deadline	Grade	Second chance
LCA	individual	2 page summary of an LCA focused on well-2wheel efficiency and CO_2 emissions	Academic level (application of theory, insight in specific case, analytical skills) -Product/report (originality/creativity, feasibility, completeness) - Process (result oriented, autonomy, reflection) -Presentation (written LCA summary)	June	grade 1 - 10	Extra 2 page
Business plan Canvas Business model	individual	a written canvas business model of the students his/her own plan, must include a separate financial, partner and competition analysis. 10 pages	- Academic level (application of theory, insight in specific case, analytical skills) -Product/report (orginality/creativity, feasibility, completeness) - Process (result oriented, autonomy, reflection) -Presentation (written summary)	June	grade 1-10	new canvas business model
Elevator Pitch	Individual	Pitch 4 minutes, 2 page summary of the 2 minutes pitch and possible SPIN strategy	- Academic level (application of theory, insight in specific case, analytical skills) -Process (result oriented, autonomy, reflection) -Presentation (and written summary)	June	ranking the pitches by the expert and audience nr 1 grade 10 nr 2 – nr 3 9 nr 4- nr 5 8 nr 6- nr 7 7 summary grade 1-10	New summary

Examination periods:

- June

Registration procedure: OSIRIS: RWVM23NBD

3. Hanze UAS SFS Exam Table 2024-2025

European Master in Renewable Energy Specialisation Semester 2 (SFS) (Hanze UAS) 2023-2024									
	Module Code	**EC**	**Exam Type**	**Written Length (hrs)**	**Assessment Object**			**1st examiner**	**2nd examiner**
Physics and Fuels	RWVM23PAF	5							
Theory	80%	4	O		Report			V. Parthasarathy	A. Perl
Lab	20%	1	O		Lab report			V. Parthasarathy	A. Perl
Bio Energy Conversion	RWVM23BEC	10							
Theory Biochemical Conversion	30%	3	O		Report			A. Perl	F. Pasquini
Lab BioFuels	20%	2	O		Lab report			F.Faber	A.Perl
Thermochemical Conversion	50%	5	O		Report			A. Perl	M. Cieplik
Power2Hydrogen	RWVM23P2U	5							
Assignment 1	60%	3	O		Report			A.Perl	V. Parthasarathy
Assignment 2	40%	2	O		Report			A.Perl	V. Parthasarathy
Sustianable Fuel Systems Design	RWVM23SFSD	5							
Assignment 1	40%	2	O		Report			J. Bekkering	E.J. Hengeveld
Assignment 2	60%	3	O		Report			E.J. Hengeveld	J. Bekkering
New Business Development	RWVM23NBD	5							
New Business Development	100%	5	O		Report			C. Vogt	J.J. Aué

Contact data

Hanze UAS
Zernikeplein 11
9747 AS Groningen

E-mail: masteremre@org.hanze.nl