

## RENEWABLE ENERGIES, ENERGY STORAGE AND HYDROGEN ECONOMY

Broad Context: Future industrial development of the World's Nations has to face the great challenges of our time, such as climate change, population growth, scarcity of primary resources, unquenchable demand for energy etc., by securing a sustainable handling of the resources of our planet. The main target is to secure the wellbeing and happiness of future generations. From this point of view the transition from fossil fuels to renewables is a key development step, but it also implies a disruptive transformation of the energy services system with political and economic implications; and it will be a long and difficult process.

Objective of the course: The main objective is to illustrate the advances in the technologies and processes for generating renewable electricity (from solar and wind energy, biomass etc.), the options to manage the power flow and store electricity, and the conversion into storable chemicals, such as hydrogen and other synthetic fuels. The interconversion between electricity and hydrogen is in fact a key element in distributing renewable energies wherever needed with the highest flexibility and security for the energy system.

### Topics of the course are:

- Hydrogen economy and circular economy: relationship, social and economic aspects and issues.
- Production of Hydrogen from renewable resources: electrolyzers, solar thermal cycles, photocatalysis, bio-H<sub>2</sub>.
- Materials for the production and storage of H<sub>2</sub>.
- H<sub>2</sub> and hydrogen-based fuels for fuel cell technologies (stationary and automotive applications).
- Decarbonisation and H<sub>2</sub> economy.
- Comparison and competitiveness evaluation with traditional and alternative technologies.

The course has been conceived in the context of the European TeachHy project, which has the mission of building a cluster of universities and other educational institutions coordinating and developing educational programmes on Fuel Cells and Hydrogen at the qualification level of undergraduate, graduate and PhD training. The course addresses the new generation of engineers (BS/MS and PhD student), scientists, economists and professionals involved in the future energy sectors. The learning outcomes of the topics covered will be verified by class tests and a final exam.

## ADMISSION AND ACCOMMODATION

The course is mainly addressed to doctoral students on first come first served basis.

The registration fee is 400,00 Euro + VAT taxes\*, where applicable (bank charges are not included).

The registration fee includes a complimentary bag, four fixed menu buffet lunches, coffee breaks, downloadable lecture notes and wi-fi internet access.

Applications should be made on-line through our web site:

[www.cism.it/en/activities/courses/E2101](http://www.cism.it/en/activities/courses/E2101)

A message of confirmation will be sent to accepted participants. Information about travel and accommodation is available on our web site, or can be mailed upon request.

A limited number of rooms is available at our Guest House at the rate of Euro 30,00 per person/night.

Applicants may cancel their course registration and receive a full refund by notifying CISM Secretariat in writing (by email) no later than two weeks prior to the start of the course.

If cancellation occurs less than two weeks prior to the start of the course, a Euro 50,00 handling fee will be charged.

Incorrect payments are subject to Euro 50,00 handling fee.

\* Italian VAT is 22%.

*For further information please contact:*

### CISM

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ACADEMIC YEAR  
2021  
University of Udine  
International Centre for Mechanical Sciences



UNIVERSITÀ  
DEGLI STUDI  
DI UDINE  
hic sunt futura



Centro Internazionale  
di Scienze Meccaniche  
International Centre  
for Mechanical Sciences

## RENEWABLE ENERGIES, ENERGY STORAGE AND HYDROGEN ECONOMY

CISM-UniUD Joint course  
coordinated by

**Marta Boaro**  
University of Udine, Italy

**Massimo Santarelli**  
Polytechnic of Turin, Italy

**Robert Steinberger-Wilckens**  
University of Birmingham, UK



Udine August 23 - 27 2021

## LECTURERS

### Prof. Fausto Gallucci

Eindhoven University, The Netherlands

*2 lectures on:*

Towards a zero-carbon society: CO<sub>2</sub> utilization technology and H<sub>2</sub> uses; Membranes for the purification of H<sub>2</sub>.

### Prof. Peter Hugh Middleton

University of Agder, Norway

*2 lectures on:*

International developments towards a hydrogen economy; Energy system cost analyses and comparison for electricity and hydrogen.

### Prof. Vladimir Molkov

Ulster University, United Kingdom

*2 lectures on:*

Fundamentals of H<sub>2</sub> safety; H<sub>2</sub> safety design tools

### Prof. Massimo Santarelli

Politecnico di Torino, Italy

*2 lectures on:*

Power to X systems based on hydrogen; Energy storage by power to gas and power to power systems.

### Prof. Robert Steinberger-Wilckens

University of Birmingham, United Kingdom

*4 lectures on:*

Renewables and energy storage strategies; H<sub>2</sub> and fuel cell technology; FC and biomass utilisation; Energy security and hydrogen – societal implications.

### Prof. Aldo Steinfeld

ETH Zurich, Switzerland

*4 lectures on:*

H<sub>2</sub> production technologies using solar energy and other renewable energy sources; Thermochemical H<sub>2</sub> production; Thermochemical water splitting.

### Prof. Jan Van Herle

Swiss Federal Institute of Technology EPFL, Lausanne, Switzerland

*3 lectures on:*

Electrolysers: Principles and fundamentals; Electrolysers: applications; Materials for hydrogen storage.

## PROGRAMME

### Monday, August 23

**12:30 - 13:30 Registration**

**13:30 - 14:00 Course Introduction**

**14:00 - 14:45 L1** Steinberger-Wilckens “Renewables and energy storage strategies”

**14:45 - 15:30 L2** Steinberger-Wilckens “H<sub>2</sub> and fuel cell technology”

**15:30 - 16:00 Coffee break**

**16:00 - 16:45 L3** Steinfeld: “H<sub>2</sub> production technologies using solar energy and other renewable energy source”

**16:45 - 17:30 L3** Steinfeld: “H<sub>2</sub> production technologies using solar energy and other renewable energy sources”

**17:30 - 18:15 L4** Gallucci “Towards a zero carbon society: CO<sub>2</sub> utilisation technology and H<sub>2</sub> uses”

### Tuesday, August 24

**8:30 - 9:15 L5** Van Herle “Electrolysers: principles and fundamentals”

**9:15 - 10:00 L6** Van Herle “Electrolysers: applications”

**10:00 - 10:30 Coffee break**

**10:30 - 11:15 L7** Molkov “Fundamentals of H<sub>2</sub> safety”

**11:15 - 12:00 L8** Molkov “H<sub>2</sub> safety design tools”

**12:00 - 14:00 Lunch**

**14:00 - 14:45 L9** Van Herle “Materials for hydrogen storage”

**14:45 - 15:30 L10** Steinfeld “Thermochemical H<sub>2</sub> production”

**15:30 - 16:00 Coffee break**

**16:00 - 16:45 L11** Steinfeld “Thermochemical water splitting”

**16:45 - 17:30 L12** Professors meet students: questions or exercises sections

**19:00 - 23:00 Social dinner**

### Wednesday, August 25

**8:30 - 9:15 L13** Santarelli “Power to X systems based on hydrogen”

**9:15 - 10:00 L14** Santarelli “Energy storage by power to gas and power to power systems”

**10:00 - 10:30 Coffee break**

**10:30 - 11:15 L15** Middleton “International development towards a hydrogen economy”

**11:15 - 12:00 L16** Gallucci “Membranes for the purification of H<sub>2</sub>”

**12:00 - 14:00 Lunch**

**14:00 - 14:45 L17** Steinberger-Wilckens “FC and biomass utilisation”

**14:45 - 15:30 L18** Middleton “Energy system cost analyses and comparison for electricity and hydrogen”

**15:30 - 16:00 Coffee break**

**16:00 - 16:45 L19** Steinberger-Wilckens “Energy security and hydrogen - societal implications”

**16:45 - 17:30 L20** Written or oral exam

### Thursday, August 26

**8:30 - 9:15 L13 L21** Preparation of the design project: forming student groups and getting organised

**10:00 - 10:30 Coffee break**

**10:30 - 12:00 L23/24** Student working time

**12:00 - 14:00 Lunch**

**14:00 - 15:30 L25/26** Student working time

**15:30 - 16:00 Coffee break**

**16:00 - 17:30 L27/28** Presentation of results of student projects

### Friday, August 27

**9:00 - 9:45 L29** Presentation of TeachHy project to the students, UniUD Departments and Academies

**9:45 - 10:30 L30** Update meeting of TeachHY project

**10:30 - 11:00 Coffee break**

**11:00 - 11:45 L31** Update meeting of TeachHY project

**11:45 - 12:30 L32** Update meeting of TeachHY project

**12:30 - 14:00 Light lunch**