

TIME TABLE

(Registration on Monday at 8.30)

TIME	Monday	Tuesday	Wednesday	Thursday	Friday
	July 20	July 21	July 22	July 23	July 24
9.00 - 9.45	Valverde	Mechleri	Mechleri	Valverde	Romeo
9.45 - 10.30	Valverde	Mechleri	Mechleri	Valverde	Romeo
11.00 - 11.45	Fennell	Fennell	Fennell	Gallucci	Valverde
11.45 - 12.30	Fennell	Fennell	Fennell	Gallucci	Valverde
14.00 - 14.45	Mechleri	Romano	Romano	Romano	
14.45 - 15.30	Mechleri	Romano	Romano	Romano	
16.00 - 16.45	Gallucci	Gallucci	Romeo	Romeo	
16.45 - 17.30	Gallucci	Gallucci	Romeo	Romeo	

ADMISSION AND ACCOMMODATION

The registration fee is of 575,00 Euro + VAT taxes*, where applicable (bank charges are not included).

The registration fee includes a complimentary bag, four fixed menu buffet lunches (Friday subject to numbers), hot beverages, downloadable lecture notes and wi-fi internet access.

Applicants must apply at least one month before the beginning of the course. Application forms should be sent on-line through our web site: <http://www.cism.it> or by post.

A message of confirmation will be sent to accepted participants. If you need assistance for registration please contact our secretariat.

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.

A limited number of participants from universities and research centres who are not supported by their own institutions can be offered board and/or lodging in a reasonably priced hotel or students' dormitories, if available.

Requests should be sent to CISM Secretariat by **May 20, 2015** along with the applicant's curriculum and a letter of recommendation by the head of the department or a supervisor confirming that the institute cannot provide funding. Preference will be given to applicants from countries that sponsor CISM.

Information about travel and accommodation is available on our web site, or can be mailed upon request.

* Italian VAT is 22%.

For further information please contact:

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 Piazza Garibaldi 18
 33100 Udine (Italy)
 tel. +39 0432 248511 (6 lines)
 fax +39 0432 248550
 e-mail: cism@cism.it



Centre International des Sciences Mécaniques
 International Centre for Mechanical Sciences

ACADEMIC YEAR 2015
 The Nieuwstadt Session

CO₂ CAPTURE TECHNOLOGIES TO MITIGATE CLIMATE CHANGE

Advanced Professional Training
 coordinated by

Jose-Manuel Valverde
 University of Seville
 Spain

Udine July 20 - 24 2015

CO₂ CAPTURE TECHNOLOGIES TO MITIGATE CLIMATE CHANGE

Scientific evidences linking the upraise of CO₂ emissions and anthropogenic climate change are overwhelming, which makes it necessary to urgently develop CO₂ capture and storage (CCS) technologies scalable to a commercial level in order to allow the continuous use of fossil fuel as a reliable source of energy on demand. Leading CO₂ capture technologies which are expected to be available in the short and long term will be reviewed in the proposed Course. More specifically, a detailed update will be outlined on leading technologies such as solvent scrubbing, oxyfuel combustion, chemical looping and calcium looping. This will include a critical review of the wide diversity of materials which are being investigated as potential CO₂ sorbents such as conventional solvents, solvent blends, biphasic solvents, ionic liquids, Metal-Organic Frameworks (MOFs), Zeolitic Imidazolate Frameworks (ZIFs), solid sorbents,

low-temperature sorbents and membranes. Experience shows that the performance of these materials must be assessed taking into account the conditions and constraints imposed by each specific application, which may play a critical role on proposed techniques for process intensification or sorbent reactivation. It is thus of paramount importance to focus theoretical and lab-scale studies on analyzing the material behavior at conditions closely mimicking those to be found at practice and to pursue a fundamental understanding on the physical-chemical processes that govern the behavior of the materials. These points will be a main focus in the Course. The Course will consider also modeling and thermodynamics of the integration of CCS and power plants, which is a critical issue to help system-scale network design and optimize post-combustion capture efficiency. Integration of CCS in gasification and steam

reforming plants for pre-combustion capture as well as integration of CCS with other CO₂ pollutants industrial processes, most notably cement manufacture, iron and steel making will also be a relevant subject of the Course. An important matter of concern that will be further considered regards energy penalties in CCS. Methods to reduce inefficiencies and increase overall performance in thermal systems will be discussed with an emphasis on currently developing techniques for their specific application to CCS.

A promising technology that will be addressed is the integration of Bioenergy and CCS (BECCS). It is believed that capture and long term storage of CO₂ produced by combustion of biomass, which matches approximately the CO₂ consumed during biomass growth, would effectively result in net removal of atmospheric CO₂ yet bringing about new serious environmental and social issues stemming from the escalating

demand for biomass. A further critical aspect for reducing carbon emissions is the utilization of CO₂ as feedstock for industrial applications. In this regard, a number of emerging technologies in petrochemical, biochemical, fuel, and power energy sector are expected to play a leading role in minimizing carbon pollution from industrial facilities. Current progress on the mature Enhanced Oil Recovery (EOR) technology will be discussed in the Course. An additional relevant subject to be considered in the Course concerns current policy and economics issues which hinder large-scale CCS deployment in the EU. The necessity of adopting new and more effective strategies will be examined.

Participation in the Course is open to doctoral students, young and senior researchers, technologists and engineers having in common an interest on CCS technologies and policy.

INVITED LECTURERS

Paul S. Fennell - Imperial College London, UK
6 lectures on: Review of fossil fuels. Development on solvent scrubbing. CO₂ capture by chemical-looping combustion. An overview of CO₂ storage methods.

Fausto Gallucci - Eindhoven University of Technology, The Netherlands
6 lectures on: Membranes for pre-combustion and post-combustion CO₂ capture. Membranes for oxy-fuel and chemical looping combustion. Membrane production and characterization. Experimental testing of novel reactors for CO₂ capture and detailed modeling.

Evgenia Mechleri - Imperial College London, UK
6 lectures on: General overview of CCS. Thermodynamic and process modelling for post-combustion CCS. Integrated power-capture plant modelling (gas- or coal- or biomass-fired plants). Carbon negative electricity generation – BECCS. CO₂ utilisation – What makes sense? Dynamic carbon negative electricity generation systems – the requirement for flexible, low carbon electricity generation. Policy and economics of CCS in an EU context .

Matteo C. Romano - Politecnico di Milano, Italy
6 lectures on: Pre-combustion capture. Integration of separation technologies in gasification and steam reforming plants. Sorption Enhanced Reforming (SER) and Sorption Enhanced water gas shift (WGS). CO₂ capture from carbon intensive industries (cement, refineries, iron and steel).

Luis M. Romeo - CIRCE, Zaragoza, Spain
6 lectures on: Energy integration in the application of carbon capture and storage (CCS) technologies (post-combustion, pre-combustion and oxyfuel combustion) to power plants. Strategies to reduce energy penalties. CO₂ capture by oxycombustion: Fundamentals and outcome from pilot-scale plants.

Jose-Manuel Valverde - University of Seville, Spain
6 lectures on: CO₂ capture by the Ca-looping process. CaO performance as CO₂ sorbent. Effect of realistic calcination conditions on post-combustion capture. Sorbent modification and techniques for reactivation.

PRELIMINARY SUGGESTED READINGS

IPCC, 2013 report; Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

IEA, 2013 report; Technology Roadmap: Carbon Capture and Storage 2013. International Energy Agency.

N. MacDowell et al. An overview of CO₂ capture technologies. *Energy Environ. Sci.*, 2010, 3, 1645-1669.

Energy Environ. Sci., 2012, Volume 5 (CO₂ Themed Collection). Includes a collection of 16 articles on the theme of CO₂.

M. E. Boot-Handford et al. Carbon capture and storage update. *Energy Environ. Sci.*, 2014, Volume 7, 130-189.

J.M. Valverde. Ca-based synthetic materials with enhanced CO₂ capture efficiency. *Journal of Materials Chemistry A*. 2013, 1, 447-468.

Romeo LM, Lara Y, Gonzalez A. Reducing energy penalties in carbon capture with Organic Rankine Cycles. *Applied Thermal Engineering*, 31, 2928-2935 (2011).

LECTURES

All lectures will be given in English. Lecture notes can be downloaded from the CISM web site, instructions will be sent to accepted participants.

**CO₂ CAPTURE TECHNOLOGIES
TO MITIGATE CLIMATE CHANGE**

Udine, July 20 - 24, 2015

Application Form
(Please print or type)

Surname _____

Name _____

Affiliation _____

Address _____

E-mail _____

Phone _____ Fax _____

Method of payment upon receipt of confirmation (Please check the box)

The fee is 575,00 Euro + 22% Italian VAT taxes, where applicable (bank charges are not included).

I shall send a check of Euro _____

Payment will be made to CISM - Bank Account No. 094570210900,
VENETO BANCA - Udine (CAB 12300 - ABI 05035 - SWIFT/BIC
VEBHIT2M - IBAN CODE IT46 N 05035 12300 09457 0210900).
Copy of the receipt should be sent to the secretariat

I shall pay at the registration counter with check or VISA Credit Card
(Mastercard/Eurocard, Visa, CartaSi)

**IMPORTANT: CISM is obliged to present an invoice for the above sum.
Please indicate to whom the invoice should be addressed.**

Name _____

Address _____

C.F.* _____

VAT/IVA* No _____

(* Only for EU residents or foreigners with a permanent business activity in Italy.)

Only for Italian Public Companies

I ask for IVA exemption (ex law n. 537/1993 - art. 14 comma 10).

Privacy policy: I understand that data received via this form will be used only to provide information about CISM and its activities, within the limits set by the Italian legislative decree no. 196/2003 and subsequent amendments.

Complete information on CISM's privacy policy is available at www.cism.it.

I have read the "Admission and Accommodation" terms and conditions and agree.

Date _____ Signature _____