

820763 - AET - Thermal Energy Storage (DRAFT VERSION)

Coordinating unit: 820 - EUETIB - Barcelona College of Industrial Engineering
Teaching unit: 724 - MMT - Department of Heat Engines
Academic year: 2014
Degree: MASTER IN ENERGY ENGINEERING (Syllabus 2013). (Teaching unit Optional)
ERASMUS MUNDUS MASTER IN ENVIRONMENTAL PATHWAYS FOR SUSTAINABLE ENERGY
SYSTEMS (Syllabus 2012). (Teaching unit Optional)
ECTS credits: 5 Teaching languages: English

Teaching staff

Coordinator: Ivette Rodríguez Pérez /Yolanda Calventus Sole.
Others: Yolanda Calventus Sole
Jesús Castro González.
Pere Colomer Vilanova
Ivette Rodríguez Pérez
Joaquim Rigola Serrano

Opening hours

Timetable: Tuesday 10-12h, Wednesday 16-18h, Thursday 15-17h

Prior skills

Fundamental aspects of thermodynamics, fluid mechanics and heat transfer and mass transfer

Requirements

Those equivalent to have passed the Master leveling course

Degree competences to which the subject contributes

Specific:

CEMT-1. Understand, describe and analyse, in a clear and comprehensive manner, the entire energy conversion chain, from its status as an energy source to its use as an energy service. They will also be able to identify, describe and analyse the situation and characteristics of the various energy resources and end uses of energy, in their economic, social and environmental dimensions, and to make value judgments.

CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.

CEMT-7. Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.

CEMT-6. Employ technical and economic criteria to select the most appropriate electrical equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technology applications in the field of production, transport, distribution, storage and use of electric energy.

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Teaching methodology

- Lecture or conferences (EXP): Lectures taught by the professors of the course as well as invited lectures.
- Interactive classes (parts): resolution of exercises, collective discussions with both the teacher and the students. Presentation by the students of exercises carried out individually or in small groups.
- Oriented theoretical-practical works (TD): completion of a classroom activity, theoretical or practical, carried out individually or in small groups with the teacher's guidance.
- Project, activity or work of reduced scope (PR): Self-learning based on accomplishing an activity of reduced scope, individually or in small groups, just applying the knowledge acquired.
- Project or work of broader scope (PA): Self-learning based on accomplishing an activity of broader scope, individually or in small groups, just applying the knowledge acquired.
- Assessment exam (EV).

Learning objectives of the subject

In the course a description of the new energy paradigm of distributed generation is presented. In this panorama the accumulation of thermal energy / thermochemical plays an important role in order to decouple power generation from consumption. It also gives a detailed description of the technologies most used in thermal and thermochemical energy storage such as thermal energy storage for sensitive and / or latent heat, fuel and cooling adsorption and absorption.

Study load

Total learning time: 125h	Hours large group:	0h	0.00%
	Hours medium group:	0h	0.00%
	Hours small group:	30h	24.00%
	Guided activities:	15h	12.00%
	Self study:	80h	64.00%

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Content

<p>Energy audits</p>	<p>Learning time: 17h Small group/Laboratory: 4h Guided activities: 2h Self study : 11h</p>
<p>Degree competences to which the content contributes: CEMT-1 (Specific) CEMT-5 (Specific)</p> <p>Description: Energy, exergy and other performance indicators. Using energy storage and heat pumps. Distributed generation and energy storage systems: co-generation, thermal cycles, heating and cooling networks.</p> <p>Related activities: -Lectures or conferences -Interactive classes -Oriented theoretical-practical works -Project, activity or work of reduced scope -Project, activity or work of broader scope</p> <p>Specific objectives: Review concepts of energy and exergy efficiencies Introduce students to the concept of distributed energy.</p>	
<p>Sensible heat storage</p>	<p>Learning time: 17h Small group/Laboratory: 4h Guided activities: 2h Self study : 11h</p>
<p>Degree competences to which the content contributes: CEMT-5 (Specific) CEMT-6 (Specific) CEMT-7 (Specific)</p> <p>Description: Passive and active systems. Main means of accumulation. Importance of thermal stratification. Strategies to enhance the thermal stratification. Quantification of thermal stratification: methods based on energy and exergy balances. Modelling the accumulation system.</p> <p>Related activities: -Lectures or conferences -Interactive classes -Oriented theoretical-practical works -Project, activity or work of reduced scope -Project, activity or work of broader scope</p> <p>Specific objectives: Description of thermal energy storage systems for heat sensitive. Introduce the students to the modeling of these systems.</p>	

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Latent heat storage	Learning time: 19h Small group/Laboratory: 4h Guided activities: 2h Self study : 13h
<p>Degree competences to which the content contributes: CEMT-5 (Specific) CEMT-6 (Specific) CEMT-7 (Specific)</p> <p>Description: Selection of phase change materials depending on the application. Types of storage systems by change of phase. Modeling of phase change systems.</p> <p>Related activities: -Lectures or conferences -Interactive classes -Oriented theoretical-practical works -Project, activity or work of reduced scope -Project, activity or work of broader scope</p> <p>Specific objectives: Description of thermal energy storage systems by latent heat. Introduce students to the modeling of these systems.</p>	

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<p>Thermal Storage Systems in concentrated solar power plants</p>	<p>Learning time: 16h Small group/Laboratory: 4h Guided activities: 1h Self study : 11h</p>
<p>Degree competences to which the content contributes: CEMT-5 (Specific) CEMT-6 (Specific)</p> <p>Description: Importance of energy storage in solar-thermal plants. taxonomy of the storage systems. Main storage media: advantages and disadvantages. Thermal energy storage system on the plant layout. Cost of accumulation system.</p> <p>Related activities: -Lectures or conferences -Interactive classes -Oriented theoretical-practical works -Project, activity or work of reduced scope -Project, activity or work of broader scope</p> <p>Specific objectives: Introduce the student into the different technologies which might be used in CSP for thermal energy storage and the role of thermal energy storage Know the different possibilities of operation of a storage system in a CSP plant Introduce in the analysis of the cost of the system and its impact in the LCOE</p>	

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<p>Thermo-chemical heat storage</p>	<p>Learning time: 15h Large group/Theory: 10h Small group/Laboratory: 4h Guided activities: 1h</p>
<p>Degree competences to which the content contributes: CEMT-5 (Specific) CEMT-6 (Specific) CEMT-7 (Specific)</p> <p>Description: Principle of operation. Reactive couples. Applications: energy storage in buildings, adsorption and absorption cooling. Developments in progress. Technological aspects.</p> <p>Related activities: -Lectures or conferences -Interactive classes -Oriented theoretical-practical works -Project, activity or work of reduced scope -Project, activity or work of broader scope</p> <p>Specific objectives: Introduction to the physical principle of sorption systems. Description of existing technologies.</p>	
<p>Electro-chemical heat storage</p>	<p>Learning time: 21h 30m Small group/Laboratory: 6h Guided activities: 2h 30m Self study : 13h</p>
<p>Degree competences to which the content contributes: CEMT-5 (Specific) CEMT-6 (Specific)</p> <p>Description: Fuel cells: theoretical basis. Operational fuel cells. Technological development of different types of batteries.</p> <p>Related activities: -Lectures or conferences -Interactive classes -Oriented theoretical-practical works -Project, activity or work of reduced scope -Project, activity or work of broader scope</p> <p>Specific objectives: Introduce the student into the technology of fuel cells. Description of existing technologies.</p>	

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<p>Hydrogen, a vector of clean energy</p>	<p>Learning time: 16h 30m Small group/Laboratory: 4h Guided activities: 1h 30m Self study : 11h</p>
<p>Degree competences to which the content contributes: CEMT-5 (Specific) CEMT-6 (Specific)</p> <p>Description: Obtention and storage of hydrogen. Processing of fuels used in different types of batteries. Conventional and non-conventional methods.</p> <p>Related activities: -Lectures or conferences -Interactive classes -Oriented theoretical-practical works -Project, activity or work of reduced scope -Project, activity or work of broader scope</p> <p>Specific objectives: Description of how to obtain and store hydrogen. Description of fuels used in different types of batteries.</p>	

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Planning of activities

lectures and theoretical classes	Hours: 20h Laboratory classes: 15h Self study: 5h
<p>Degree competences to which the activity contributes:</p> <p>Description: The content of the course is taught following an expository and participative model. The material is organized into different groups according to the content areas of knowledge of the subject.</p> <p>Support materials: Recommended bibliography. Slides of the course</p> <p>Descriptions of the assignments due and their relation to the assessment: This activity is evaluated in conjunction with activity 2 (problems) via assessment exercises and tests of knowledge.</p> <p>Specific objectives: At the end of this activity, students should be able to master the knowledge, consolidate and apply them correctly to various technical problems. Moreover, being a subject techno applied the lectures should serve as a complement to other technical subjects related to the field heat as Refrigeration and Solar Heat Engines.</p>	
participative classes	Hours: 20h Laboratory classes: 15h Self study: 5h
<p>Degree competences to which the activity contributes:</p> <p>CEMT-6 (Employ technical and economic criteria to select the most appropriate electrical equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technology applications in the field of production, transport, distribution, storage and use of electric energy.)</p> <p>CEMT-7 (Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.)</p> <p>Description: During these activities, problems and exercises will be conducted using a participatory model class. On each topic, there will be some problems in class so that students can acquire the necessary methodology to carry out their resolution: simplifying assumptions, numerical resolution, discussion of the results.</p> <p>Support materials: Basic and complementary bibliography. Teacher slides</p> <p>Descriptions of the assignments due and their relation to the assessment: This activity is evaluated in conjunction with activity 1 (theory) via assessment exercises and tests of knowledge.</p> <p>Specific objectives: At the end of this activity, students should be able to apply their theoretical knowledge to solve different kinds of problems. Given the methodology the student should be able to:</p> <ol style="list-style-type: none"> 1- Understand and analyze the problem statement. 2 - Set up and develop a methodology for the resolution of the problem 3 - Solve the problem with a suitable resolution algorithm. 4. - Critically interpret the results. 	

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<p>Oriented theoretical-practical works</p>	<p>Hours: 17h Guided study: 4h 30m Laboratory classes: 7h 30m Self study: 5h</p>
<p>Degree competences to which the activity contributes: CEMT-7 (Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.)</p> <p>Description: The works consist of solving small problems, which the basic data can be both from the results of a laboratory or proposed by the professor. The structure to be followed: -Set up of the practice following the guidelines given via the professor notes. -The students will be organised in small groups of 2-3 students and the maximum duration of the activity will be 2 hours. - Results and discussion -Completion of a report on the results carried out considering the questions posed by the professor and the conclusions drawn. This report will be evaluated together with the completion of the practice.</p> <p>Support materials: Bibliography and professor notes</p> <p>Descriptions of the assignments due and their relation to the assessment: Report on the results</p> <p>Specific objectives: Consolidate the knowledge acquired in theory and practice classes.</p>	
<p>Reduced scope work</p>	<p>Hours: 25h Self study: 25h</p>
<p>Degree competences to which the activity contributes: CEMT-6 (Employ technical and economic criteria to select the most appropriate electrical equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technology applications in the field of production, transport, distribution, storage and use of electric energy.) CEMT-7 (Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.)</p> <p>Description: To solve complex problems based on situations posed by the teacher.</p> <p>Support materials: Bibliography and professor notes</p> <p>Descriptions of the assignments due and their relation to the assessment: Report on the results</p> <p>Specific objectives: Consolidate the knowledge acquired in theory and practice classes.</p>	

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Broader scope work	Hours: 40h Self study: 40h
<p>Degree competences to which the activity contributes:</p> <p>CEMT-5 (Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.)</p> <p>CEMT-6 (Employ technical and economic criteria to select the most appropriate electrical equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technology applications in the field of production, transport, distribution, storage and use of electric energy.)</p> <p>CEMT-7 (Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.)</p> <p>Description: The student will deepen into a subject and will solve a problem in which there must be necessary to apply different concepts acquired in the course. It is expected that the student is capable of using the different methodologies taught in class in order to accomplish the work.</p> <p>Descriptions of the assignments due and their relation to the assessment: Report on the results</p> <p>Specific objectives: Expand and consolidate the knowledge acquired in theory and practice classes.</p>	

Assessment exams	Hours: 3h Guided study: 3h
<p>Degree competences to which the activity contributes:</p> <p>CEMT-1 (Understand, describe and analyse, in a clear and comprehensive manner, the entire energy conversion chain, from its status as an energy source to its use as an energy service. They will also be able to identify, describe and analyse the situation and characteristics of the various energy resources and end uses of energy, in their economic, social and environmental dimensions, and to make value judgments.)</p> <p>CEMT-5 (Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.)</p> <p>CEMT-6 (Employ technical and economic criteria to select the most appropriate electrical equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technology applications in the field of production, transport, distribution, storage and use of electric energy.)</p> <p>CEMT-7 (Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.)</p> <p>Description: Theoretical and practice exercises on the different subjects of the course will be assessed</p> <p>Support materials: Written questionnaire</p> <p>Descriptions of the assignments due and their relation to the assessment: The posed questions and their answers on the different topics will be handed in to the professor at the end of the exam</p>	

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Specific objectives:

Assess the acquired knowledge throughout the course

Qualification system

- Final exam (PE): 50%
- Assessment exercises (individually or in small groups) (TR): 40%
- Attendance and participation in classes and laboratories (AP): 5%
- Quality and performance of the work in groups (TG): 5%
- Final exam (PE): 50%
- Assessment exercises (individually or in small groups) (TR): 40%
- Attendance and participation in classes and laboratories (AP): 5%
- Quality and performance of the work in groups (TG): 5%

Regulations for carrying out activities

- Final exam (PE): There will be a final exam for the course. Students must complete both theoretical questions and problems related to theoretical and practical content of the course. Reviews and / or complaints regarding exams will be conducted in accordance with the dates and times established in the academic calendar.
- Assessment exercises (TR): Students must follow the instructions explained in class and contained in the work file that will be proposed to the students. As a result of these activities, the student must submit a report (preferably in pdf format) to the teacher, within the deadline fixed for each activity. The assessment will involve both its realization as a possible defense.
- Attendance and participation in classes and laboratories (AP): Laboratory practices are assessed both during the development of the lab and by accomplishing a practical exercises proposed; The report resulting from the lab will be handed in to the professor following the instructions given in class. The assessment will involve both practical realization, as a possible defense.
- Quality and performance of group work (TG): Practices and class exercises will be assessed individually or in small groups by means of their oral defense if necessary.
- Final exam (PE): There will be a final exam for the course. Students must complete both theoretical questions and problems related to theoretical and practical content of the course. Reviews and / or complaints regarding exams will be conducted in accordance with the dates and times established in the academic calendar.
- Assessment exercises (TR): Students must follow the instructions explained in class and contained in the work file that will be proposed to the students. As a result of these activities, the student must submit a report (preferably in pdf format) to the teacher, within the deadline fixed for each activity. The assessment will involve both its realization as a possible defense.
- Attendance and participation in classes and laboratories (AP): Laboratory practices are assessed both during the development of the lab and by accomplishing a practical exercises proposed; The report resulting from the lab will be handed in to the professor following the instructions given in class. The assessment will involve both practical realization, as a possible defense.
- Quality and performance of group work (TG): Practices and class exercises will be assessed individually or in small groups by means of their oral defense if necessary.

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Bibliography

Basic:

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Kordesch, Karl; Simader, Günter. Fuel cells and their applications. Weinheim [etc.]: VCH, cop. 1996. ISBN 3527285792.

Complementary:

Nield, Donald A; Bejan, Adrian. Convection in porous media. New York, [etc.]: Springer, cop. 2013. ISBN 9781461455400.

Duffie, John A; Beckman, William A. Solar engineering of thermal processes [Rekurs electrònic]. 4th ed. Chichester: Wiley, 2013. ISBN 9781118671603.

Alefeld, Georg; Radermacher, Reinhard. Heat conversion systems. Boca Raton [etc.]: CRC Press, cop. 1994. ISBN 0849389283.

Bogart, Marcel. Ammonia absorption refrigeration in industrial processes. Houston [etc.]: Gulf Publishing, 1981. ISBN 0872010279.

Larminie, James; Dicks, Andrew. Fuel cell systems explained. 2nd ed. Chichester [etc.]: John Wiley & Sons, cop. 2003. ISBN 047084857X.

Others resources:

Audiovisual material

- professor slides

- Course slides

Computer material

- Professor notes

- Professor notes