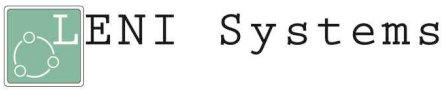

Advanced Energetics

Objectives of the lecture and organisation

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Titre / Title	**Advanced energetics (ME-451)**

Enseignant(s) / Instructor(s)	**Maréchal François: GM**	Langue / Language	**EN**

Programme(s) Période(s)	Nombre d'heures / Number of hours	Spéc / filière /orient	Type
Génie mécanique (2011-2012, Master semestre 1)	**C: 3 H hebdo, Ex: 2 H hebdo**	***D***	**opt**
Génie mécanique (2011-2012, Master semestre 3)	**C: 3 H hebdo, Ex: 2 H hebdo**	***D***	**opt**
Gestion de l'énergie et construction durable - master (2011-2012, Master semestre 1)	**C: 3 H hebdo, Ex: 2 H hebdo**		**opt**
Mineur en Énergie (2011-2012, Semestre automne)	**C: 3 H hebdo, Ex: 2 H hebdo**		**opt**

Objectifs d'apprentissage:

Compétences de domaine:
• Maîtriser les notions de rendements thermodynamiques, E6
• Etablir un diagramme de flux et calculer les bilans de matière et d'énergie de processus industriels, E22
• Analyser l'efficacité énergétique et le rendement exergétique des systèmes énergétiques industriels, E23
• Connaître les principales technologies de conversion de l'énergie, leurs principes et leurs limites, E7
• Comprendre les enjeux de l'énergie: les ressources, les services énergétiques, les impacts économiques et environnementaux, E9
Compétences transversales:
• Rédiger un rapport d'étude scientifique ou technique, T6
• Réaliser une présentation orale, T7
• Documenter et communiquer un projet, T12
• Analyser les conséquences d'une décision ou d'une solution, T20

Contenu:

Analyse et synthèse de l'utilisation et conversion rationnelle de l'énergie dans les procédés industriels.
Méthodologie de l'audit énergétique d'un processus industriel. Principes de l'analyse exergétique des processus industriels et des systèmes de conversion d'énergie. Principes de l'intégration des processus avec la méthode du pincement. Identification des options d'amélioration du rendement de processus. Intégration optimale de de la conversion d'énergie. Evaluation thermo-économique des options de réduction de la consommation énergétique. Etude de cas d'un processus industriel.

Mots clés:

Utilisation rationnelle de l'énergie, Conversion de l'énergie, Analyse exergétique, Analyse pincement, Procédés industriels

Prérequis:

• Maîtriser les notions de bilans de matière, d'énergie et de quantité de mouvement, E1 (Thermodynamique et énergétique I)
• Calculer les propriétés thermodynamiques d'un fluide, E2 (Thermodynamique et énergétique I)
• Maîtriser les notions de transfert de chaleur et de masse, E3 (Heat and mass transfer)
• Comprendre les principaux cycles thermodynamiques, E5 (Thermodynamique et énergétique I)
• Calculer et concevoir des échangeurs de chaleur, E15 (Heat and mass transfer)
• Notion d'optimisation (Introduction à l'optimisation différentiable)

Forme d'enseignement:

Le cours est organisé en sessions théoriques et comprend la résolution d'un cas d'étude réalisée dans un projet de groupe.

Forme du contrôle:

Présentation de groupe du cas d'étude. Examen oral sur l'application de la théorie au cas d'étude.

Learning outcomes:

Domain skills:
• Master the concepts of thermodynamic efficiency, E6
• Establish the flow diagram of an industrial process and calculate the corresponding energy and mass balance, E22
• Analyse the energy and exergy efficiency of industrial energy systems, E23
• Know the principles and limitations of the main energy conversion technologies, E7
• Understand the challenges related to energy: resources, energy services, economic and environmental impacts, E9
Transversal skills:
• Write a scientific or technical report, T6
• Make an oral presentation, T7
• Document and communicate a project, T12
• Analyse the consequences of a decision or solution, T20

Content:

Rational use and conversion of energy in industrial processes.

Methodology for the energy efficiency audit of industrial processes. Principles of the exergy analysis of industrial processes and energy conversion systems. Principles of the process integration using the pinch analysis method. Identification of the process efficiency improvement options. Optimal integration of the energy conversion systems. Thermo-economic evaluation of energy savings options. Application to one industrial process case study.

Keywords:

Energy efficiency, heat recovery, Energy conversion, Exergy analysis, Pinch analysis, Industrial processes

Required prior knowledge:

• Master the concepts of mass, energy, and momentum balance, E1 (Thermodynamique et énergétique I)
• Compute the thermodynamic properties of a fluid, E2 (Thermodynamique et énergétique I)
• Master the concepts of heat and mass transfer, E3 (Heat and mass transfer)
• Understand the main thermodynamic cycles, E5 (Thermodynamique et énergétique I)
• Calculate and design heat exchangers, E15 (heat and mass transfer)
• Notion of optimization (Introduction à l'optimisation différentiable)

Type of teaching:

The course is organised as theoretical sessions and the resolution of a real case study to be realised in a team project.

Form of examination:

The real case study will be presented (group presentation). An oral exam will concern the application of the theory in the case study.

Bibliographie et matériel:

Le matériel de référence peut être téléchargé depuis le site moodle (http://moodle.epfl.ch/course/view.php?id=141). Le polycopié du cours peut être commandé.

Matière examinée / subjects examined	Session	Coefficient / Crédits ECTS	Forme de l'examen / Type of examination
Advanced energetics	**HIV**	**5**	**Oral**

1 Course Information and organisation

Semester	*Master*1*or*3 (autumn)
Duration	14 x (3+2) hours
Web :	http ://moodle.epfl.ch/
Place	Monday 13h15-18h00, MEB331
Lecturer	Francois Marechal LENI-ISE-STI-EPFL STATION 9 Tel + 41 21 693 35 16 E-mail : francois.marechal@epfl.ch Bureau ME A 2 402
Assistant	Nasibeh Pouransari nasibeh.pouransari@epfl.ch - ME A2 396 Matthias Bendig matthias.bendig@epfl.ch - ME A2 425 Dr. Leandro Salgueiro leandro.salgueiro@epfl.ch - ME A2 393
Avalability	Please contact us during the lecture

2 Courses organisation

2.1 Lecture notes and other documentation

Lecture notes can be downloaded from the moodle web site http ://moodle.epfl.ch.

Printed copies are available on request (1 week delivery), a sum of 25 CHF will be asked for these paper copies.

PDF of the slides will be available for download on the moodle platform and will not be distributed.

2.2 The moodle platform

The moodle platform http ://moodle.epfl.ch is used to distribute the documents and other materials required for the lecture. Each week the slides of the corresponding lectures will be available for download and a short summary of the lecture is given.

You have to consult the moodle platform in order to confirm the lectures that are given as well as the location.

2.3 Exercises

Following the schedule on moodle, exercises are proposed. There will be four exercises which will be prepared by groups of 4 persons. The results have to be handed in, in form of a report. Each group member is responsible for one of the exercises and has to "sign" for it. The exercises are evaluated and the quality will have an influence of the final grade of the respective responsible. The criteria for the evaluation are the solution of the exercises and as well the form of the report. The report is expected to be written following the guidelines which can be found on the LENI website (under > student projects > Documents)

2.4 Project

In the second part of the lecture (from week 4), you will be asked to realise a process integration study. This study will result in a report that will serve as a basis for the examination. The

project is realised within a team, the results will be presented orally on week 14 and a report has to be produced.

Each member is suppose to understand what is written in the report. Regular reviewmeetings will be organised with the supervisor. The meeting is prepared by the group based on a slide presentation to allow the supervisor to assess the work that has been done and fix the next goals. The major results of the project will be presented at the end of the semester (week 14).

When possible, project are proposed and evaluated by an expert from the industry.

2.5 Feedback

Feedback will be given to students that request it. The feedback will be given if a meeting is organised and if the questions and other materials are prepared. It is recommended to organise group meetings in order to avoid repetitions.

2.6 Evaluation

The lecture is evaluated in an individual oral exam. The exam has 2 parts : a preparation phase during which the student is asked to prepare an answer to a specific question referring to the project report and to present the answer to the examiner and another part related to the theory developed during the course. It is expected that the full content of the lecture is covered by the exam.

The report is including into the final grade, the jury will have however the possibility of giving the priority to the oral exam when fixing the final grade.

3 Specific objectives

At the end of the course, the student will be able to
- Analyse a process as a system considering not only the process operations but also all the enabling processes and the energy conversion units.
- Analyse the energy efficiency of an industrial process by analysing process flowsheets and analysing the process unit operation and the way they are integrated.
- Analyse the exergy efficiency of process units and of industrial energy systems
- Identify possible energy savings by heat recovery and design the heat recovery exchanger network
- Analyse the integration of the energy conversion systems and design efficient integrated energy conversion systems
- Thermo-economically evaluate energy savings options.

4 Detailed specific goals of the course

The following tables should help you assessing your progress. By filling the bullets you should be able to follow your progress during the lecture.

4.1 Minimum Energy requirement

	Goals
ooooo	Compute the energy bill of an industrial system
ooooo	Explain what is the meaning of the $\Delta Tmin$ and what are the major parameters that define its value
ooooo	Define hot and cold streams for a process integration analysis
ooooo	Compute the energy balance of an industrial system including the application of First Law balances to verify the coherency of the data set.
ooooo	Explain the construction of the hot and cold composite curves
ooooo	Explain the construction and the use of the grand composite curve
ooooo	Compute the maximum energy recovery in an industrial process and compute its minimum energy requirement
ooooo	Explain the major assumptions and how these can be assessed or overcome
ooooo	Estimate the heat recovery heat exchanger network cost and compute the optimal $\Delta Tmin$ value of the plant.
ooooo	Identify and quantify pinch violations in a process
ooooo	Explain the More-in More-out principle
ooooo	Explain the plus-minus principle
ooooo	Identify ways to improve the minimum energy requirement from the analysis of the composite curves

4.2 Exergy analysis

	Goals
ooooo	Explain what is exergy and how exergy balances can be formulated on the basis of First and Second Laws of Thermodynamics
ooooo	Explain what is exergy analysis and explain the different types of exergy losses : thermal, chemical,..
ooooo	Characterize the exergy losses of a given process unit operation
ooooo	Realise the exergy analysis of an industrial system
ooooo	Explain the application of exergy analysis principles in the field of process integration

4.3 Heat exchanger network design

	Goals
ooooo	State the problem of the heat exchanger network design
ooooo	Explain the major rules of the pinch design method
ooooo	Apply the pinch design method to an example
ooooo	Simplify a heat exchanger network design by following loops and path
ooooo	Compare heat exchanger network design options
ooooo	Explain and apply the remaining problem analysis
ooooo	Explain the principles of the heat load distribution calculation
ooooo	Formulate the problem of the optimisation of the heat exchanger network design.

4.4 Energy conversion systems integration

	Goals
ooooo	Explain the use of the Grand composite curve to characterise the energy conversion system
ooooo	Explain the principles of the integration of energy conversion systems
ooooo	Explain the integration of combustion and the conditions under which the efficiency can be improved using air preheating
ooooo	Explain the principle of the integration of a combined heat and power production units
ooooo	Explain how to solve the problem of the optimal integration of a steam network
ooooo	Explain the conditions of the integration of heat pumping systems
ooooo	Explain the integration of refrigeration systems
ooooo	Explain the integration of utility systems with multiple utility streams
ooooo	Explain the use of mathematical programming models to compute the optimal integration of energy conversion systems
ooooo	Explain the calculation of integrated composite curves of a sub-system

Table follows on the next page

	Goals
ooooo	Explain how exergy analysis helps designing well integrated energy conversion systems

4.5 Energy efficiency audits in industrial processes

	Goals
ooooo	What is the importance of the industry in the energy consumption of a country, what are the trends, what is the role of the energy efficiency with respect to such situation
ooooo	What the energy intensity of a process
ooooo	How to compute the energy cost of a production
ooooo	How to estimate the investment and evaluate the profitability of a energy saving investment
ooooo	What are the major steps of an energy audit in the industry, who is involved, what are the rules, etc...
ooooo	What are the major process flow diagrams, when to use which one, process flowsheet simplification for heat requirement definition and process integration analysis
ooooo	Define an industrial system, what are the boundaries, etc...
ooooo	Explain when and how to apply process integration techniques to study the energy efficiency of an industrial process

4.6 Application

	Goals
ooooo	Explain the steps followed during the process integration project
ooooo	Explain the major assumptions and limit of the study
ooooo	Explain the calculation of the minimum energy requirement
ooooo	Explain the integration of the energy conversion system and in particular the integration of the cogeneration unit using a internal combustion engine.
ooooo	Thermodynamically evaluate the solutions proposed
ooooo	Present the results in a report
ooooo	Use computer tools to solve the problem