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# ENGINEERING PROGRAMME

2023-2024

Year 2 / Year 3

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Specialisation option

## Energy Production and Management

OD ENERG

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PROGRAMME SUPERVISOR

Jean-François HETET



# Autumn Semester

Course unit	ECTS Credits	Track	Course code	Title
UE 73 / 93	12	Core course	COMBU THCYM THERM TUMAC	Combustion for energetic processes Thermodynamic of engines Applied thermodynamics for energetic processes Turbomachinery
UE 74 / 94	13	Core course	ECONV EDCAR P1ENERG SOLAR TSCGE	Conventional energies Low-carbon energies Project 1 Solar captation Transport - storage - conversion - energy management

# Spring Semester

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Course unit	ECTS Credits	Track	Course code	Title
UE 103 / 83	14	Core course	BCAUE GCLIM P2ENERG THBATE TPENE	Carbon balance and energy auditing Heating and air-conditioning systems Project 2 Thermal performance of buildings Practical work

## ENGINEERING - OD ENERG

Year 2 / Year 3 - Autumn Semester - Course Unit 73 / 93

# Combustion for energetic processes [COMBU]

LEAD PROFESSOR(S): Alain MAIBOOM

### Objectives

The main objectives are:

- To provide fundamental knowledge on combustion and pollutant emission formation,
- To present some technical aspects of the combustion process in machines (internal combustion engine, gas turbines, boilers, wood stoves) and strategies to reduce pollutant emissions.

### Course contents

The fundamental aspects of combustion are presented in the first part of the course, according to the following plan :

- Brief introduction to combustion phenomena and the main applications
- Initial and final state: thermodynamics, equilibrium
- Chemical kinetics
- Reactive flow governing equations
- Auto-ignition
- Gaseous premixed flames
- Laminar diffusion flames
- Auto-ignition
- Gaseous premixed flames
- Laminar diffusion flames (mixing fraction Z)
- Introduction to turbulent flames

In a second part, technical aspects of combustion chambers, combustion, pollutant emissions formation and reduction are described. Practical class exercises are conducted. Main aspects of this second part are :

- Combustion chambers of internal combustion engines (spark ignition and compression ignition) : fuel injection systems (port injection, direct injection, multi injection), air-fuel ratio control, power management, formation of particulate matter, NO<sub>x</sub>, CO and unburn hydrocarbons, ways to control emissions in the combustion chamber (trade-off).
- Combustion chambers of gas turbines : injection systems, premixed and mixing-controlled combustion, basics of combustion architecture, control of pollutant emissions.
- Various fuels, in particular synthetic fuels (hydrogen, NH<sub>3</sub>, methanol,...) and their use in thermal machines.
- Biomass burning : qualitative presentation of burners (stove, wood boilers), CO<sub>2</sub> balance.

### Course material

- Poinot & Veynante, Theoretical and Numerical Combustion
- <http://elearning.cerfacs.fr/combustion/index.php>

### Assessment

Collective assessment: EVC 1 (coefficient 0.25)

Individual assessment: EVI 1 (coefficient 0.75)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	20 hrs	10 hrs	0 hrs	0 hrs	2 hrs

## ENGINEERING - OD ENERG

Year 2 / Year 3 - Autumn Semester - Course Unit 73 / 93

# Thermodynamic of engines [THCYM]

*LEAD PROFESSOR(S): Georges SALAMEH*

### Objectives

The objectives of this course are to:

- Provide core knowledge on internal combustion engines, with a focus on thermodynamic aspects
- Characterize the cycles and behavior of gas turbines and steam cycles used in electricity production.

### Course contents

For piston engines the course will present: a historical perspective, thermodynamic and mechanical principles, technological aspects; types of engine; engine geometry performance and efficiency; applications, hybridation, energy recovery; intake and exhaust system; supercharging and turbocharging; emission reduction; cooling, lubrication and friction.

With regard to gas turbines (GT) and steam turbines (ST) the course focuses mainly on the description and operation of thermodynamic cycles (Carnot, Joule for GT, Rankine, Hirn with/without overheating, steam extraction, supercritical cycles). Real cycles are also described (irreversibilities, pressure losses) as well as the means to increase performance (combined cycles, cogeneration).

The course includes practical exercises on performance and efficiency evaluation.

Please note that fuel systems and combustion processes of these thermal machines are covered in the 'Combustion and pollutant emissions' course. The fundamental aspects of gas dynamics and turbomachinery are addressed in the Gas Dynamics and Turbomachinery courses.

### Course material

J.B Heywood, Internal Combustion Engines - Fundamentals, Mac Graw Hill, 2011

W.W. Pulkrabek, Engineering Fundamentals of the Internal Combustion Engine, Prentice Hall, 2003

### Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	26 hrs	4 hrs	0 hrs	0 hrs	2 hrs

## ENGINEERING - OD ENERG

Year 2 / Year 3 - Autumn Semester - Course Unit 73 / 93

# Applied thermodynamics for energetic processes [THERM]

LEAD PROFESSOR(S): Pascal CHESSE

### Objectives

The objective of this course is to provide a good understanding of energy concepts that may be useful to any engineer working in the field of energy production and management.

### Course contents

The first part of this course is an introduction to thermal radiation.

The basics of heat transfer are presented in the second part with an application to real systems. Conduction and convection are introduced in this context. Then, a thermal analysis of a heat exchanger is undertaken to introduce the notion of logarithmic average value of temperature and the NUT number. This part of the course concludes with a case study on an exchanger.

In the last part of the course the notion of exergy is introduced. Exergy leads to a better representation of the energy transfer in any system taking into account irreversibility (second law of thermodynamics). How to make an energy and exergy balance is the objective of this part with an application to some real systems (compressor, turbine, heat exchanger).

Lectures will be followed by a series of application exercises related to energy production and management.

### Course material

Michel FEIDT - Energétique : Concepts et Applications, Dunod Ed. (2006)

Lucien BOREL and Daniel FAVRAT - Thermodynamique et Energétique : de l'énergie à l'exergie, Presses polytechniques et universitaires romandes (2005)

Richard E. SONNTAG, Claus BORGNAKKE and Gordon J. VAN WYLEN - Fundamentals of thermodynamics, Ed. Wiley & Sons (1998)

Renaud GICQUEL - Systèmes énergétiques (3 volumes), Presses des Mines Paris Tech (2009)

### Assessment

Collective assessment: EVC 1 (coefficient 0.25)

Individual assessment: EVI 1 (coefficient 0.75)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	8 hrs	22 hrs	0 hrs	0 hrs	2 hrs

## ENGINEERING - OD ENERG

Year 2 / Year 3 - Autumn Semester - Course Unit 73 / 93

# Turbomachinery [TUMAC]

*LEAD PROFESSOR(S): Pascal CHESSE*

### Objectives

The objective of this course is to explain the operation of incompressible fluid turbomachinery (pump, hydraulic turbine) and compressible fluid turbomachinery (turbine, compressor) and their applications in the field of energy production.

### Course contents

The course begins with a presentation of the general working principles of a turbomachine and a classification of turbomachines. The Euler theorem is then introduced followed by the layout and functioning of a centrifugal pump: wheel, diffuser, volute. The course then deals with machine yield, cavitation and Rateau coefficients. The second part of the course deals with compressible fluid, including centrifugal compressor and similitude conditions. The lectures will be followed by a series of application exercises related to the field of energy production and then a lecture on wind turbines.

### Course material

M. SEDILLE, Turbomachines hydrauliques et thermiques, Tomes 1,2,3, Masson Paris  
M. PLUVIOSE, Turbomachines, Vuibert Ed.

### Assessment

Collective assessment: EVC 1 (coefficient 0.25)

Individual assessment: EVI 1 (coefficient 0.75)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	8 hrs	22 hrs	0 hrs	0 hrs	2 hrs

## ENGINEERING - OD ENERG

Year 2 / Year 3 - Autumn Semester - Course Unit 74 / 94

# Conventional energies [ECONV]

*LEAD PROFESSOR(S): Jean-François HETET*

### Objectives

This course provides a broad overview of the different types of conventional energy.

### Course contents

Part 1 (16 hrs) intervention by M. Postaire (engineer at the EDF nuclear power plant of Chinon): fundamental aspects on nuclear energy, technical aspects for the control of a nuclear reactor for electric production.

Part 2 (10 hrs) Presentations on:

1. Oil - History of consumption, current global situation in terms of production, consumption and resources, prices, prospects. Shale oil.
2. Gas - History of consumption, current global situation in terms of production, consumption and resources, prices, prospects. Shale gas.
3. Coal - History of consumption, current global situation in terms of production, consumption and resources, prices, prospects.
4. Oil crises - History of crises since 1900. Origins and characteristics of the 1973, 1979, and 1986 crises. Geopolitical considerations. Global economic consequences. Prospects
5. Hydraulic power - General working principles. Different dam types. Prospects.
6. Geothermal energy - General working principles. Resources and examples. Prospects
7. Concentrated solar power - General working principles. Examples. Prospects
8. Biomass (except biofuels) - Sources. Different sectors. Mechanisation. Prospects.
9. Bio-fuels - Production methods. Environmental impact. Assessment of well-to-wheel.
10. Energy consumption in the future (world and France). Overview of current global energy resources. Forecasted consumption to 2020. Long-term problems posed by energy consumption and potential solutions. Prospects for the 2100s.
11. Energy saving in the world and in France - Grey energy. Energy management and energy saving certificates. Energy performance. Recycling and waste recovery (glass, paper, plastic etc). Examples.
12. Carbon collection and storage - Different collection methods.

Part 3 (4hrs): post-treatment of pollutant emissions from thermal power plants

### Course material

### Assessment

Individual assessment: EVI 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	30 hrs	0 hrs	0 hrs	0 hrs	2 hrs



## ENGINEERING - OD ENERG

Year 2 / Year 3 - Autumn Semester - Course Unit 74 / 94

### Low-carbon energies [EDCAR]

*LEAD PROFESSOR(S): Jean-François HETET*

#### Objectives

This course presents an overview of low-carbon energies.

#### Course contents

Part 1 (4hrs): intervention by Mrs AUBRUN (Professor Centrale NANTES) on wind energy  
 Part 2 (12hrs): intervention by Mr. Joubert (Professor -IMN) on fuel cells and hydrogen  
 Part 3 (4hrs): intervention by Mr. Babarit (LHEEA) on marine renewable energy - wave power systems  
 Part 4 (4hrs): intervention by Mr. BITTAN (EDF) on risk management in nuclear energy  
 Part 5 (4hrs) : intervention by Mr. MARTINETTI (Nantes Métropole) on heat networks

#### Course material

#### Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	30 hrs	0 hrs	0 hrs	0 hrs	2 hrs

## ENGINEERING - OD ENERG

Year 2 / Year 3 - Autumn Semester - Course Unit 74 / 94

### Project 1 [P1ENERG]

*LEAD PROFESSOR(S): Jean-François HETET*

#### Objectives

Undertake a collaborative project (2/3 students) on energy engineering.

#### Course contents

Examples:

Design, manufacturing and experimentation of an air solar collector

Design and testing of a model of a wind mill

Study of inter-seasonal heat storage

Study of a concentrated solar collector

Study of a CHP system with combined cycles

#### Course material

#### Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	1	0 hrs	0 hrs	0 hrs	32 hrs	0 hrs

## ENGINEERING - OD ENERG

Year 2 / Year 3 - Autumn Semester - Course Unit 74 / 94

# Solar captation [SOLAR]

LEAD PROFESSOR(S): *Pierre MARTY*

### Objectives

Understand and master the detailed concepts of harnessing solar energy and all solar energy conversion systems. Students will have to master the fundamental equations and large orders of magnitude, know how to do "back of an envelope" calculations to quickly analyze a solution while developing a sharp critical sense.

### Course contents

- 1 - Solar energy collection
- 2 - Solar thermal
- 3 - Concentrated solar power
- 4 - Passive solar energy
- 5 - Solar photovoltaic

### Course material

J. Bernard, *Energie Solaire Calculs & Optimisation Génie Energétique Niveau B*, 2e édition. Paris: Ellipses Marketing, 2011.

J.-P. Oliva et S. Courgey, *La conception bioclimatique: Des maisons économes et confortables en neuf et en réhabilitation. terre vivante*, 2006.

« Le capteur solaire à eau chaude », *Energie+*. <https://www.energieplus-lesite.be/index.php?id=16760> (consulté le janv. 24, 2019).

Syndicat des énergies renouvelables, « Principe de fonctionnement du solaire thermodynamique », 2012.

W. Weiss et M. Spörk-Dür, « Solar Heat Worldwide », *IEA Solar Heating & Cooling Programme*, 2020. Consulté le: oct. 13, 2020. [En ligne]. Disponible sur: <https://www.iea-shc.org/solar-heat-worldwide>.

### Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	20 hrs	10 hrs	0 hrs	0 hrs	2 hrs

## ENGINEERING - OD ENERG

Year 2 / Year 3 - Autumn Semester - Course Unit 74 / 94

# Transport - storage - conversion - energy management [TSCGE]

*LEAD PROFESSOR(S): Jean-François HETET*

### Objectives

This course presents the issues associated with managing, transporting and storing energy.

### Course contents

Part 1 (8hrs): intervention of M. GAUBICHER (IMN-CNRS): different ways of storing energy with a focus on batteries

Part2 (6hrs): intervention of M. Dedieu (GRT Gaz): gas transport

Part3 (16hrs): intervention of a team from RTE on electricity transport (networks, dispatching, smart grids, etc.)

Visit to the RTE electricity dispatch center in la Chapelle-sur-Erdre.

### Course material

### Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	32 hrs	0 hrs	0 hrs	0 hrs	0 hrs

## ENGINEERING - OD ENERG

Year 2 / Year 3 - Spring Semester - Course Unit 103 / 83

# Carbon balance and energy auditing [BCAUE]

*LEAD PROFESSOR(S): Jean-François HETET*

### Objectives

This course presents two tools that are necessary for engineers who want to integrate environmental aspects in the design of a product, a system, or a method: the carbon balance and energy auditing.

### Course contents

#### Part 1: Carbon Balance

The carbon balance of a product or a human entity is a tool to account for greenhouse gas emissions, which allows for effective solutions to be proposed to reduce conventional energy consumption and to study the vulnerability of an economic activity or a community with regards to fossil fuel dependency.

#### Part 2: Energy Audit

The energy audit has become compulsory for large companies. The objective is to identify potential for energy savings and to set up an energy efficiency policy. The impact of the circular economy on the reduction of primary energy consumption will be also covered.

### Course material

### Assessment

Collective assessment: EVC 1 (coefficient 0.5)

Individual assessment: EVI 1 (coefficient 0.5)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	22 hrs	10 hrs	0 hrs	0 hrs	0 hrs

## ENGINEERING - OD ENERG

Year 2 / Year 3 - Spring Semester - Course Unit 103 / 83

# Heating and air-conditioning systems [GCLIM]

*LEAD PROFESSOR(S): David CHALET*

### Objectives

The objective of this course is to study the different technical solutions to heat and cool the air of a building as well as solutions for obtaining domestic hot water.

### Course contents

In the first part of the course, an introduction will present the different categories of heating and DHW systems and the role of each of the elements (generators, emitters, distribution systems). A complete presentation of the different conventional heat generators will be provided (classification of boilers, water heater, looping hot water and regulation), as well as the generators using renewable energy (geothermal, aerothermal, aquathermal, wood, etc). The possible couplings between the different systems (heating and DHW), whether traditional or renewable, will be presented.

Subsequently, the issue of water distribution will be covered (composition of the various circuits, materials, hydraulic balancing, regulation ...). This part will conclude with an implementation of practical examples and a company visit.

The second part of the course covers air conditioning. First, an overview will be provided (control of ambient temperature and humidity etc). Then, a load calculation is carried out in order to define the different air treatment operations. All technical solutions for treating air will be addressed. A real case will be studied.

### Course material

### Assessment

Collective assessment: EVC 1 (coefficient 0.2)

Individual assessment: EVI 1 (coefficient 0.8)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	26 hrs	4 hrs	0 hrs	0 hrs	2 hrs

## ENGINEERING - OD ENERG

Year 2 / Year 3 - Spring Semester - Course Unit 103 / 83

### Project 2 [P2ENERG]

*LEAD PROFESSOR(S): Jean-François HETET*

#### Objectives

To be involved in a collaborative project (2/3 students) on energy engineering.

#### Course contents

Examples:

Design, manufacturing and experimentation of an air solar collector

Design and testing of a model of a wind mill

Study of inter-seasonal heat storage

Study of a concentrated solar collector

Study of a CHP system with combined cycles

#### Course material

#### Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	2	0 hrs	0 hrs	0 hrs	48 hrs	0 hrs

## ENGINEERING - OD ENERG

Year 2 / Year 3 - Spring Semester - Course Unit 103 / 83

# Thermal performance of buildings [THBATE]

*LEAD PROFESSOR(S): Alain MAIBOOM*

### Objectives

This course provides fundamental practical knowledge for the design of building envelopes from a thermal perspective (new builds and thermal renovation of existing buildings).

### Course contents

The course outlines the tools and calculation methods to approach the design of a building from a thermal perspective, using a steady-state method and a dynamic simulation method.

The first part of the course begins with an overview of the main ideas, some key figures, the energy context for the building sector and introduces the concept of thermal comfort. Then the course addresses the main calculation methods within the regulatory context (RE 2020), with steady-state assumption, heat loss through the envelope, how to insulate a building etc. Strategies to curb heat loss via thermal bridges and air exchange (double flow ventilation) are also covered.

In the second part training is provided on how to use Pleiades COMFIE software, which is used to perform dynamic thermal simulations of buildings, essential in the new regulatory environment. It can be particularly useful for the estimation of thermal comfort and energy efficiency in the winter and summer months.

### Course material

- [1] Ministère de la transition écologique, Chiffres clés de l'énergie, Édition 2021.
- [2] ADEME, Climat, Air et Energie - Les chiffres clés, 2018.
- [3] J.-P. Oliva and S. Courgey, La conception bioclimatique: Des maisons économes et confortables en neuf et en réhabilitation. terre vivante, 2006.
- [4] ADEME, Le confort d'été - Guide de l'ADEME. 2007.
- [5] Ministère de la transition écologique et de la cohésion des territoires, Guide RE2020 - Eco-construire pour le confort de tous.
- [6] Guide pratique CSTB: Les ponts thermiques dans le bâtiment - mieux les connaître pour mieux les traiter
- [7] RE 2020 et rénovation énergétique - Guide pratique pour les bâtiments neufs et existants - Maisons et copropriétés - Sénova - Collection Eyrolles Environnement

### Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	26 hrs	4 hrs	0 hrs	0 hrs	2 hrs



## ENGINEERING - OD ENERG

Year 2 / Year 3 - Spring Semester - Course Unit 103 / 83

### Practical work [TPENE]

LEAD PROFESSOR(S): Vincent BERTHOMÉ

#### Objectives

To understand the theoretical notions seen in the first year energy course by manipulating various thermal machines.

#### Course contents

Various partical work are available:

- Air conditioning
- Heat pump
- Heat transfer on bars
- Solar collectors
- Heat exchangers
- Nozzles
- Small engine test bench

#### Course material

#### Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	0 hrs	0 hrs	32 hrs	0 hrs	0 hrs