Master Energy
Energy Technology Options for a Carbon Free Future

Master 2

Programme Content

Core module	80 h 9 ECTS
Introduction to energy	
Energy systems thermodynamic modeling	
Life cycle of energy systems	
Energy Efficiency	**90 h 10 ECTS**
High energy efficient industrial processes: From energy integration to innovative design	
Energy efficiency of urban systems and buildings	
Energy efficiency in mobility systems	
Decarbonation of fuels	**99h 11 ECTS**
Extraction processes	
Alternative fuels : H2, biomass, synthetic fuels	
CO_2 emissions treatment: capture, recovery and storage	
Plasma assisted thermochemical processes	
Renewable Energy/electricity grids/storage	**90h 10 ECTS**
Renewable technologies	
Renewable energy integration	
Storage	
Sustainable Energy and Materials	**90h 10 ECTS**
Introduction	
Solar photovoltaics	
H_2 technology : fuel cells, hydrogen production and storage	
Batteries et supercapacitors	
New approaches	

- CORE MODULE

Introduction to Energy	
Course main content	General introduction to Energy and renewable Energy Introduction to Energy Economy and Energy Markets Oil, fuels, well to wheel analysis, oil refining Natural Gas, reserves, infrastructures, markets Electricity (demand/supply balance, French-European market operation) Nuclear Renewable energy (Hydro, Photovoltaics, Biomass, Wind) Hydrogen Energy storage
Learning outcomes	You will be able to : - Describe the physical and economic transformation between different types of energy. - Describe each energy chain, identify related energy conversion systems and explain the associated technological, economic or environmental problems. - Identify key energy actors and ongoing research.

Energy System Thermodynamic Modeling	
Course main content	Modeling of working fluids: State variables, phase change, numerical models of fluid properties 1st and second principles, cycle elementary components modeling: heat exchanger, compressor, turbine, valves, reservoirs Combustion : fuels, chemical reaction mechanisms, heat calorific value and adiabatic temperature Engine/Gas turbine Cold generation / heat pumps / Steam cycle power plant Methods to analyse performance: energy and exergy balances Combined cycle gas turbine / Cogeneration / Trigeneration Gas separation: distillation, absorption
Learning outcomes	You will be able to : - Describe the main thermodynamic cycles of the energy systems - Identify opportunities to improve the cycles' performance - Model the main cycles of heat conversion (for work, heat and cold generation) using professional software (Dymola / Modelica) - Design and optimize an advanced thermodynamic cycle based on a functional specification and on specified constraints.

Life Cycle of Energy Systems	
Course main content	Introduction and Life cycle costs evaluation, investments and exploitation costs Life cycle analysis GHG emissions accounting Measurement and uncertainties Embodied energy Externalities of energy Economics of energy and environment policies
Learning outcomes	You will be able to : - Describe and implement life cycle assessment methods for energy projects from an energy, economic and environmental perspective - Discovery of different energy problems and in each case of the nature of the decision criteria associated. - Develop life cycle modeling and analysis competences in the comparison of different energy systems.

- ENERGY EFFICIENCY

High energy-efficient industrial processes: from energy integration to innovate design	
Course main content	Pinch analysis: determination of minimal energy required, maximum energy potential recovery, identification of the sources of energy inefficiency Introduction to mathematic optimizations: MILP, MINLP, genetic algorithms Eco-industrial park and circular economy Methodologies for multi-scales process integration: • Static, batch or dynamic processes • Matter integration (in order to reduce primary material) • Heat transfer network between industrial plants
Learning outcomes	You will be able to : - Identify the energy efficiency issues of industrial processes - Explain and apply the process integration methodologies - Design high energy-efficient processes - Use energy integration software

Energy efficiency of Urban Systems and Buildings	
Course main content	Building Energy Simulation • Building thermal model (heat losses, solar and internal gains) • Modal reduction technique District Buildings interaction (shading) Urban Energy Simulation and Energy Systems Management • Databases for territory description • Models simplification and uncertainties within fast calculation Building Systems modelling and simulation of DSM strategies
Learning outcomes	You will be able to : - Simulate the thermal energy performances of the building - Manage large databases for energy building simulations at city scale - Model energy systems in building

Energy efficiency of mobility systems	
Course main content	Panorama of mobility systems : energy consumption evolution and GHG emissions, Mobility systems : collective (plane, train, bus), personal (cars) Vehicles architectures: hybrids (parallel/serie), electrical cars, energy recovery (deceleration, exhaust gazes…) Energy storage and conversion for electrified vehicles: batteries, hydrogen Energy management in mobility systems : thermal comfort management, AC and heating systems, On board component thermal management
Learning outcomes	You will be able to : - Identify the energy efficiency issues of mobility systems - Understand the electrification impact in term of energy efficiency increase and decarbonation - New issues linked with electrification (energy storage and conversion, thermal confort…)

- DECARBONATION OF FUELS

Extraction Processes	
Course main content	Introduction to Recovery Hydrocarbons Actors Perspectives Flow in porous media: Darcy's law, Permeability, porosity, hydraulic conductivity, Numerical simulation Characterization of pore flows Enhanced oil recovery: the chemistry Formulation of surfactants and polymer Enhanced oil recovery: foams
Learning outcomes	You will be able to: - Know the actors in the oil sector - Know how to model the flow in a porous. - Know Secondary and tertiary hydrocarbon recovery techniques - Know the methods of experimental studies

Alternative fuels: H2, biomass and synthetic fuels	
Course main content	**Hydrogen:** Properties and industrial applications. Safety and environment impact Production with low direct emission of CO_2: low and high temperature electrolysis Thermal decomposition, photo-electrochemistry Tank design for storage applications Application in the energy field**:** Combustion (hythane) ; Fuel cells transportation, stationary and mobile applications, renewable energy storage Cost and efficiency of the different conversion processes **Biomass/biogas**: Analyse of resources and classification Thermochemical conversion of biomass: pyrolysis, gasification, reforming, combustion. Hydrogen and BtL processes (Biomass to Liquid); Fischer-Tropsch processes. Biofuels
Learning outcomes	You will be able to: - Define and alternative fuel - List, differentiate and describe the properties of an alternative fuel - Describe a conversion process - Adapt a conversion process depending on the fuel

CO2 emissions treatment: capture, recovery, storage	
Course main content	Capture processes : Capture by chemical absorption, Oxy-combustion dedicated to the CO2 capture. Pre-combustion CO2 capture from natural gas reforming. CO2 capture by cryogenics. Benchmarking of Cryogenic technologies, process principles and crystallization phenomena (nucleation), comparison of performance with conventional capture technologies. Simulation of refrigeration machines and optimization of cold production, concepts of exergy at low temperature. Underground storage of CO2. Thermodynamic properties on mixing properties CO2 + X or Y for CO2 storage Solubilisation and valorisation of CO2; Solubilisation and CO2 removal in Ionic liquids; molten carbonates case: a new way of purifying and exploiting carbon dioxide.
Learning outcomes	You will be able to : Design a CO2 capture and recovery process

Plasma assisted processing	
Course main content	Plasma processing: introduction, physico-chemical properties, and applications, history, technologies Applications of plasmas in the field of thermochemical conversion of hydrocarbons (fossil, renewable, wastes): direct decarbonization, gasification, CO2 retro-conversion, gas depollution Microplasmas and applications in the field of energy and environment Microplasmas and applications in the field of chemical molecules synthesis
Learning outcomes	You will get : - Physico-chemical plasma processing basic knowledge - Knowledge of main applications in the field of Energy and environment

- RENEWABLE ENERGY/ELECTRICTY GRID/STORAGE

"Meteo-dependent" Renewable Technologies	
Course main content	Introduction to meteo-dependent renewable energy specificity **Wind energy** : Resource assessment/prediction, aerodynamics, conversion technologies, Off-shore **Solar energy** : Resource assessment/prediction , PV technology and system performance Concentrating power system **Marine technologies** : Resource assessment/prediction , conversion technologies LCA of Renewable Energy technologies
Learning outcomes	You will get : - understanding of Renewable resource assessment and intermittency - Good knowledge of technology conversion - Assessment of their environmental impact

Renewable energy integration	
Course main content	Electricity market simulation Introduction to the electric power system : Description and operation, Prices and costs, electric demand, thermo-sensitivity, acceptability Decision making for the electric power system : Optimal power flow, security constrained optimal power flow, economic dispatch Electric Power Markets : Futures, Energy, day ahead and intra day, network services Distribution networks : Planning and sizing, Renewables and distribution network, storage in the distribution network Impact of RE : Power plant sizing, network reinforcements, market participation
Learning outcomes	You will get : - Understanding of the electric power system operation - Knowledge of major Issues regarding the integration of renewables in the electric power system

Electricity storage	
Course main content	Electricity storage technologies : Cost, performance and maturity Electricity storage services and benefits Methods and evaluation tool for Electricity storage performance assessment Which business model? Systems installation : Feed back from the field New approaches : mechanical, chemical
Learning outcomes	You will get : - Good knowledge of the electricity storage technologies - Good apprehension of the impact of electricity storage on grids

- SUSTAINABLE ENERGY AND MATERIALS

Introduction	
Course main content	Key aspects of materials for energy Synthesis and characterisation of functional materials for energy Multi-scale modeling
Learning outcomes	You will get a good understanding of : - Impact of the choice of materials in different energy domains, especially for Renewable Energy; - Synthesis and characterization processes of different types of materials, depending on their specific role; - Multi-scale approach of modeling to describe and analyze the structure and properties of materials for energy.

Photovoltaics	
Course main content	Introduction, general overview, technologies, history, solar resource Working principle of solar cells Si technology + introduction on other technologies (II and III generations) PV systems, solar farms, building-integrated PV (BI-PV), floating PV, PV for mobility (ship, plane, car, …) PV Life-cycle assessment
Learning outcomes	You will get : - Solid knowledge on PV conversion: issues, challenges, environmental impacts - Physical working principle of photovoltaic conversion in solar cells - Knowledge of the various PV technologies and their specificities - Fabrication and characterization techniques of materials for PV

Fuel cells, production and storage of hydrogen	
Course main content	Introduction on conversion and electrochemical storage. Principles, materials, challenges and panorama of fuel cells. Low and high-temperature fuel cells + new concepts . Materials for water electrolysis for hydrogen and valorisation of carbon dioxide. Cracking, photoelectrolysis. Role of functional thin layers in fuel cells and electrolysers. Materials for energy storage.
Learning outcomes	You will be able to : - Define and compare fuel cells and electrolysers; - Describe methods and materials for the production and storage of energy; - Describe and understand the functionalities of materials for fuel cells and electrolysers - Explain the role of nanomaterials in the mentioned electrochemical devices; - Describe new concepts; - Analyse industrial and economic feasibility.

Batteries and supercapacitors	
Course main content	General principles and classification of batteries. Concepts, materials and performance of Pb, Ni-Cd and metal-hydride batteries. Lithium-ion batteries, state of the art and advances on materials. New generation batteries: Li-air, Li-S, Zn-air, … and electrolytes (ionic liquids, solids,…) Management, security and recycling issues. Interest and performances of supercapictors.
Learning outcomes	You will be able to : - Define and compare the principles, working operation and performance of batteries; - Define the features of the different types of lithium batteries; - Describe and understand electrodes and electrolyte materials for Li-ion batteries; - Define new concepts and evolution prospects in batteries; - Analyse industrial and economic feasibility; - Define and describe supercapacitors

Other applications and new approaches	
Learning outcomes	Other ways of producing electricity: hydroelectricity, wind, thermoelectricity, ….: Principles, applications and materials overview. Thermo-electricity Thermal storage Thermal (super)insulation: application to the building (materials, properties and components) Piezoelectric for renewable energies
Learning outcomes	You will be able to : - Extend the field beyond solar, hydrogen and electrochemical storage, - Master the materials and their challenges (notably for the building "but not only")