



**MASTER'S DEGREE IN ENERGY**

**UNIVERSITÉ PSL**

**Master Energy**  
**Energy Technology Options for a Carbon Free Future**

*Master 2*



## Programme Content

<b>Core module</b>	<b>30 h 9 ECTS</b>
Introduction to energy	
Energy systems thermodynamic modeling	
Life cycle of energy systems	
<b>Energy Efficiency</b>	<b>90 h 9 ECTS</b>
High energy efficient industrial processes:	
Energy efficiency of urban systems and buildings	
Energy efficiency in mobility systems	
<b>Decarbonation of fuels</b>	<b>90h 9 ECTS</b>
Alternative fuels	
Carbon Capture and Storage	
EE of Urban Systems and buildings	
<b>Renewable Energy Integration</b>	<b>90h 9 ECTS</b>
Power systems	
Resources	
Storage	
<b>Renewable Energy Technologies</b>	<b>90h 9 ECTS</b>
Solar photovoltaics	
Fuel cells	
Batteries et supercapacitors	
<b>Recycling processes and the energy transition</b>	<b>90h 9 ECTS</b>
Overview of recycling processes	
Dynamic modelling of processes: application to recycling and reaction	
Hazardous processes analysis	
Artificial Intelligence	
English course	
French course	

## - CORE MODULE

Introduction to Energy	
<b>Course main content</b>	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
<b>Learning outcomes</b>	You will be able to : <ul style="list-style-type: none"> <li>- Describe the physical and economic transformation between different types of energy.</li> <li>- Describe each energy chain, identify related energy conversion systems and explain the associated technological, economic or environmental problems.</li> <li>- Identify key energy actors and ongoing research.</li> </ul>

Energy System Thermodynamic Modeling	
<b>Course main content</b>	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
<b>Learning outcomes</b>	You will be able to : <ul style="list-style-type: none"> <li>- Describe the main thermodynamic cycles of the energy systems</li> <li>- Identify opportunities to improve the cycles' performance</li> <li>- Model the main cycles of heat conversion (for work, heat and cold generation) using professional software (Dymola / Modelica)</li> <li>- Design and optimize an advanced thermodynamic cycle based on a functional specification and on specified constraints.</li> </ul>

## Life Cycle of Energy Systems

<b>Course main content</b>	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
<b>Learning outcomes</b>	You will be able to : <ul style="list-style-type: none"><li>- Describe and implement life cycle assessment methods for energy projects from an energy, economic and environmental perspective</li><li>- Discovery of different energy problems and in each case of the nature of the decision criteria associated.</li><li>- Develop life cycle modeling and analysis competences in the comparison of different energy systems.</li></ul>

## ENERGY EFFICIENCY

High energy-efficient industrial processes: from energy integration to innovate design	
<b>Course main content</b>	<p>Pinch analysis: determination of minimal energy required, maximum energy potential recovery, identification of the sources of energy inefficiency</p> <p>Introduction to mathematic optimizations: MILP, MINLP, genetic algorithms</p> <p>Eco-industrial park and circular economy</p> <p>Methodologies for multi-scales process integration:</p> <ul style="list-style-type: none"> <li>• Static, batch or dynamic processes</li> <li>• Matter integration (in order to reduce primary material)</li> <li>• Heat transfer network between industrial plants</li> </ul>
<b>Learning outcomes</b>	<p>You will be able to :</p> <ul style="list-style-type: none"> <li>- Identify the energy efficiency issues of industrial processes</li> <li>- Explain and apply the process integration methodologies</li> <li>- Design high energy-efficient processes</li> <li>- Use energy integration software</li> </ul>

Energy efficiency of Urban Systems and Buildings	
<b>Course main content</b>	<p>Building Energy Simulation</p> <ul style="list-style-type: none"> <li>• Building thermal model (heat losses, solar and internal gains)</li> <li>• Modal reduction technique</li> </ul> <p>District Buildings interaction (shading)</p> <p>Urban Energy Simulation and Energy Systems Management</p> <ul style="list-style-type: none"> <li>• Databases for territory description</li> <li>• Models simplification and uncertainties within fast calculation</li> </ul> <p>Building Systems modelling and simulation of DSM strategies</p>
<b>Learning outcomes</b>	<p>You will be able to :</p> <ul style="list-style-type: none"> <li>- Simulate the thermal energy performances of the building</li> <li>- Manage large databases for energy building simulations at city scale</li> <li>- Model energy systems in building</li> </ul>

Energy efficiency of mobility systems	
<b>Course main content</b>	<p>Panorama of mobility systems : energy consumption evolution and GHG emissions, Mobility systems : collective (plane, train, bus), personal (cars)</p> <p>Vehicles architectures: hybrids (parallel/serie), electrical cars, energy recovery (deceleration, exhaust gases...)</p> <p>Energy storage and conversion for electrified vehicles: batteries, hydrogen</p> <p>Energy management in mobility systems : thermal comfort management, AC and heating systems, On board component thermal management</p>
<b>Learning outcomes</b>	<p>You will be able to :</p> <ul style="list-style-type: none"> <li>- Identify the energy efficiency issues of mobility systems</li> <li>- Understand the electrification impact in term of energy efficiency increase and decarbonation</li> <li>- New issues linked with electrification (energy storage and conversion, thermal confort...)</li> </ul>

## DECARBONATION OF FUELS

Alternative fuels: H2, biomass and synthetic fuels	
Course main content	<p><b>Hydrogen:</b>            Properties and industrial applications. Safety and environment impact            Production with low direct emission of CO<sub>2</sub>: low and high temperature electrolysis            Thermal decomposition, photo-electrochemistry            Tank design for storage applications            Application in the energy field: Combustion (hydrothane) ; Fuel cells            transportation, stationary and mobile applications, renewable energy storage Cost and efficiency of the different conversion processes</p> <p><b>Biomass/biogas:</b>            Analyse of resources and classification            Thermochemical conversion of biomass: pyrolysis, gasification, reforming, combustion.            Hydrogen and BtL processes (Biomass to Liquid); Fischer-Tropsch processes. Biofuels</p>
Learning outcomes	You will be able to: <ul style="list-style-type: none"> <li>- Define and alternative fuel</li> <li>- List, differentiate and describe the properties of an alternative fuel</li> <li>- Describe a conversion process</li> <li>- Adapt a conversion process depending on the fuel</li> </ul>
Carbon Capture and Storage	
Course main content	<p>Capture processes : Capture by chemical absorption, Oxy-combustion dedicated to the CO<sub>2</sub> capture. Pre-combustion CO<sub>2</sub> capture from natural gas reforming.            CO<sub>2</sub> 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 CO<sub>2</sub>. Thermodynamic properties on mixing properties CO<sub>2</sub> + X or Y for CO<sub>2</sub> storage            Solubilisation and valorisation of CO<sub>2</sub>; Solubilisation and CO<sub>2</sub> removal in Ionic liquids; molten carbonates case: a new way of purifying and exploiting carbon dioxide.</p>
Learning outcomes	You will be able to : Design a CO <sub>2</sub> capture and recovery process
Plasma assisted processing	
Course main content	<p>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, CO<sub>2</sub> retro-conversion, gas depollution            Microplasmas and applications in the field of energy and environment            Microplasmas and applications in the field of chemical molecules synthesis</p>
Learning outcomes	You will get : <ul style="list-style-type: none"> <li>- Physico-chemical plasma processing basic knowledge</li> <li>- Knowledge of main applications in the field of Energy and environment</li> </ul>

## RENEWABLE ENERGY INTEGRATION

Powers systems	
<b>Course main content</b>	<p>Introduction to meteo-dependent renewable energy specificity</p> <p><b>Wind energy :</b> Resource assessment/prediction, aerodynamics, conversion technologies, Off-shore</p> <p><b>Solar energy :</b> Resource assessment/prediction , PV technology and system performance Concentrating power system</p> <p><b>Marine technologies :</b> Resource assessment/prediction , conversion technologies LCA of Renewable Energy technologies</p>
<b>Learning outcomes</b>	<p>You will get :</p> <ul style="list-style-type: none"> <li>- understanding of Renewable resource assessment and intermittency</li> <li>- Good knowledge of technology conversion</li> <li>- Assessment of their environmental impact</li> </ul>

Resources	
<b>Course main content</b>	<p>Electricity market simulation</p> <p>Introduction to the electric power system : Description and operation, Prices and costs, electric demand, thermo-sensitivity, acceptability</p> <p>Decision making for the electric power system : Optimal power flow, security constrained optimal power flow, economic dispatch</p> <p>Electric Power Markets : Futures, Energy, day ahead and intra day, network services</p> <p>Distribution networks : Planning and sizing, Renewables and distribution network, storage in the distribution network</p> <p>Impact of RE : Power plant sizing, network reinforcements, market participation</p>
<b>Learning outcomes</b>	<p>You will get :</p> <ul style="list-style-type: none"> <li>- Understanding of the electric power system operation</li> <li>- Knowledge of major Issues regarding the integration of renewables in the electric power system</li> </ul>

Storage	
<b>Course main content</b>	<p>Electricity storage technologies : Cost, performance and maturity</p> <p>Electricity storage services and benefits</p> <p>Methods and evaluation tool for Electricity storage performance assessment</p> <p>Which business model?</p> <p>Systems installation : Feed back from the field</p> <p>New approaches : mechanical, chemical</p>
<b>Learning outcomes</b>	<p>You will get :</p> <ul style="list-style-type: none"> <li>- Good knowledge of the electricity storage technologies</li> <li>- Good apprehension of the impact of electricity storage on grids</li> </ul>

## RENEWABLE ENERGY TECHNOLOGIES

Photovoltaics	
Course main content	<p>Introduction, general overview, technologies, history, solar resource</p> <p>Working principle of solar cells</p> <p>Si technology + introduction on other technologies (II and III generations)</p> <p>PV systems, solar farms, building-integrated PV (BI-PV), floating PV, PV for mobility (ship, plane, car, ...)</p> <p>PV Life-cycle assessment</p>
Learning outcomes	<p>You will get :</p> <ul style="list-style-type: none"> <li>- Solid knowledge on PV conversion: issues, challenges, environmental impacts</li> <li>- Physical working principle of photovoltaic conversion in solar cells</li> <li>- Knowledge of the various PV technologies and their specificities</li> <li>- Fabrication and characterization techniques of materials for PV</li> </ul>

Fuel cells, production and storage of hydrogen	
Course main content	<p>Introduction on conversion and electrochemical storage.</p> <p>Principles, materials, challenges and panorama of fuel cells.</p> <p>Low and high-temperature fuel cells + new concepts .</p> <p>Materials for water electrolysis for hydrogen and valorisation of carbon dioxide. Cracking, photoelectrolysis.</p> <p>Role of functional thin layers in fuel cells and electrolysers.</p> <p>Materials for energy storage.</p>
Learning outcomes	<p>You will be able to :</p> <ul style="list-style-type: none"> <li>- Define and compare fuel cells and electrolysers;</li> <li>- Describe methods and materials for the production and storage of energy;</li> <li>- Describe and understand the functionalities of materials for fuel cells and electrolysers</li> <li>- Explain the role of nanomaterials in the mentioned electrochemical devices;</li> <li>- Describe new concepts;</li> <li>- Analyse industrial and economic feasibility.</li> </ul>

Batteries and supercapacitors	
Course main content	<p>General principles and classification of batteries.</p> <p>Concepts, materials and performance of Pb, Ni-Cd and metal-hydrate batteries.</p> <p>Lithium-ion batteries, state of the art and advances on materials.</p> <p>New generation batteries: Li-air, Li-S, Zn-air, ... and electrolytes (ionic liquids, solids,...)</p> <p>Management, security and recycling issues.</p> <p>Interest and performances of supercapacitors.</p>
Learning outcomes	<p>You will be able to :</p> <ul style="list-style-type: none"> <li>- Define and compare the principles, working operation and performance of batteries;</li> <li>- Define the features of the different types of lithium batteries;</li> <li>- Describe and understand electrodes and electrolyte materials for Li-ion batteries;</li> <li>- Define new concepts and evolution prospects in batteries;</li> <li>- Analyse industrial and economic feasibility;</li> <li>- Define and describe supercapacitors</li> </ul>

## RECYCLING PROCESSES AND THE ENERGY TRANSITION

Overview of recycling processes	
Course main content	
Learning outcomes	

Dynamic modelling of processes: application to recycling and reaction	
Course main content	
Learning outcomes	

Hazardous processes analysis	
Course main content	
Learning outcomes	