**EU Renewable Energy Masters**

**SPECIALISATION "STARS" SYLLABUS**
**Solar Thermal & Associated Renewable Storage**

| Contents: | TOTAL HOURS | ECTS |
|---|---|---|
| 1. Fundamentals | 60 | 6 |
| 2. Simulation and system optimization | 60 | 6 |
| 3. Energy | 60 | 6 |
| 4. Renewable storage | 60 | 6 |
| 5. Project, case study and innovation | 40 | 6 |
| TOTAL HOURS | 280 | 30 |

| Module 1: Fundamentals, 6 ECTS | | | |
|---|---|---|---|
| **Syllabus** | **Lectures** | **Tutorials** | **Laboratory** |
| **Reminder (1.0) , 3 ECTS** | | | **15** |
| • Heat transfer<br>• Materials | | | 10<br>5 |
| **Combined heat and mass transfer (1.1)** | **15** | | **10** |
| • Conduction<br>Fundamental Equations<br>Balance equations<br>Examples<br>• Convection<br>Fundamental Equations<br>Forced Convection (resolution of the Couette flow with temperature)<br>Natural Convection (approximation of Boussinesq)<br>Adimensionnal equations<br><br>Introduction to CFD | | | <br><br><br><br><br><br><br><br><br><br>10 |
| **Radiative heat transfer (1.2) , 3 ECTS** | **20** | | |
| • Fundamentals of Thermal Radiation<br>• Radiative Exchange between Surfaces<br>  • Radiative properties of opaque surfaces<br>  • View factors<br>  • Radiative exchange between grey and diffuse surfaces<br>• Equation of Radiative Transfer in Participating Media<br>• Radiative Properties of Participating Media<br>  • Radiative properties of molecular gases<br>  • Radiative properties of particulate media<br>• Radiative Transfer through Participating Media | | | |
| **Learning outcomes** | | | |
| The student will be familiar with radiative heat transfer and be practised in solving problems including radiation. | | | |
| **Module total** | **35** | | **25** |

| Module 2 : Simulation and system optimization, 6 ECTS | | | |
|---|---|---|---|
| **Syllabus** | **Lectures** | **Tutorials** | **Laboratory** |
| **Solar Conversion (solar heating/cooling) Thermo-economics (2.1) , 3 ECTS** | **20** | **10** | |
| • Electricity market<br>• Solar energy conversion (Cooling, heating and/or power generation<br>• Energy systems optimization | 7<br>7<br>6 | 3<br>3<br>4 | |
| **Solar concentrating systems and receiver (2.2) , 3 ECTS** | **10** | **10** | **10** |
| • The solar resource for concentrating systems<br>• Introduction to concentration optics<br>• Linear concentration: trough and linear Fresnel<br>• Point concentration: Dish and Tower (Central receiver systems)<br>• High concentration systems: solar furnace and compound parabolic concentrator (CPC)<br>• Solar receivers (absorbers) for linear concentrators<br>• Solar receivers for point focusing systems | 3<br>3<br>2<br>2 | <br>2<br>2<br>2<br>2<br>2 | |
| **Learning outcomes** | | | |
| The student will be familiar with simulation tool and optimization method dedicated to CSP. | | | |
| **Module total** | **30** | **20** | **10** |

| Module 3 : Energy, 6 ECTS | | | |
|---|---|---|---|
| **Syllabus** | **Lectures** | **Tutorials** | **Laboratory** |
| **Solar Collectors theory and technologies (3.1) , 3 ECTS** | **20** | **7** | **10** |
| • Energy collection and heat transfer in solar collectors – characteristics of materials | 6 | 2 | |
| • Design and simulation | 6 | | |
| • Overview of the solar collectors technologies | 4 | 3 | |
| • Implementation | 4 | 2 | 10 |
| **Solar power plants (3.2), 3 ECTS** | **15** | **8** | |
| • Introduction to Concentrating Solar Power (CSP): various options, plants in operation, industry | 5 | 3 | |
| • Tools for CSP design and performance evaluation | 5 | 3 | |
| • Techno-economics of CSP | 5 | 2 | |
| **Learning outcomes** | | | |
| The student will be familiar with solar collectors design and technologies and with solar power plants technologies for energy applications. | | | |
| **Module total** | **35** | **15** | **10** |

| Module 4 : Renewable Storage, 6 ECTS | | | |
|---|---|---|---|
| **Syllabus** | **Lectures** | **Tutorials** | **Laboratory** |
| **Thermal storage (4.1), 3 ECTS** | **20** | **10** | |
| • Overview of thermal storage (TS)<br>• Needs of TS in solar applications<br>• Available technologies (sensible, latent heat, thermochemical, ...)<br>• Related materials<br>• Heat transfer interfaces and fluids<br>• Implementation of TS<br>• Management and strategy of TS | | | |
| **Solar fuels (4.2), 3 ECTS** | **20** | **10** | |
| • $H_2$ from decarbonization of hydrocarbons<br>o Reforming/Gasification<br>o Cracking<br>o Carbothermal reduction | 6 | 3 | |

| | | | |
|---|---|---|---|
| • $H_2$ from water<br>  ○ Electrolysis/Thermolysis<br>  ○ Thermochemical cycles<br>• Routes towards synthetic liquid fuels<br>• Solar chemical reactors | 6<br><br><br>2<br>6 | 3<br><br><br><br>4 | |
| **Learning outcomes** | | | |
| The student will be familiar with both storage materials and technologies. He will also be familiar with the different routes foreseen to produce solar fuels in order to store solar energy. | | | |
| **Module total** | **30** | **15** | **5** |

| **Module 5 : Project, case study and innovation, 6 ECTS** | | | |
|---|---|---|---|
| **Syllabus** | **Lectures** | **Tutorials** | **Laboratory** |
| **Innovative materials for energy conversion (5.1), 3 ECTS** | **10** | **5** | **5** |
| • Selective surfaces for solar receiver<br>• Materials for low temperature solar application<br>• Thermos optical properties of materials for solar thermal applications | | | |
| **Project, case study (5.2), 3 ECTS** | **5** | **15** | |
| • Project<br>• Case study: Parabolic trough plant<br>• Case study: Central receiver plant<br>• Case study: Dish-engine plant | 5 | <br>5<br>5<br>5 | |
| **Learning outcomes** | | | |
| The student will be familiar with innovative materials for energy conversion and able to choose which one is the most adapted for a specific solar application. He will be able to analyse different case study related to CSP technologies. | | | |
| **Module total** | **15** | **20** | **5** |