DOMAINE SCIENCES, TECHNOLOGIES, SANTE
PROGRAMME PEDAGOGIQUE MASTER 2

# MASTER CHEMISTRY

**Major Biorefinery**

**Co-accredited institutions: Lille University**
**Taught in English**

Application form

## Contact

Frédéric Cazaux: frederic.cazaux@centralelille.fr

## Objectives

The Biorefinery master's degree (major) is an international multidisciplinary program (more than half of the master's students are non-French speaking), and is therefore taught in English. This particular environment provides master's students with a fairly unique opportunity to meet both a rich and varied education but also different cultures. Company visits, bibliographic reviews commissioned by industrial partners as well as courses offered by these same partners allow students to create a professional network which is essential for the rest of their career. The Biorefinery major is unique in France and finds very little competition in the world. It benefits from a network of both academic and industrial partners on a national and international scale which allows a very interesting student placement rate both during internships but also after graduation.

The Biorefinery major of the Chemistry master's degree aims to train specialists capable of becoming involved in issues of biomass recovery, of innovating in its conversion processes and of contributing to the replacement of processes using fossil resources. They will provide solutions for the implementation of new reactions involving molecules resulting from the treatment of biomass. To do this, they will master:

- The composition of the various biomasses as well as their cultivation method, rotation at land level, etc.
- The principles of the bio-economy in order to establish the "right" biorefinery according to the local environment.
- Chemical, physical and biotechnological means to transform biomass (plants, wood, algae) into its unit components (cellulose, hemicellulose, lignin).
- The upgrading of the components and functional groups of these molecules into biofuels and / or chemical synthons.
- At the end of this program, graduates can apply for a PhD or work in industry.

## International perspective

The Bioref 2nd year of Master stems from a reflection carried out following a European research contract (EUROBIOREF) on the subject of "the biorefinery of tomorrow". Within the consortium formed by around thirty industrial and academic partners, it has been concluded that one of the solutions to get past the fossil era was to use biomass, but that no training was available for future researchers (Bac +8) and engineers (Bac +5) in the sector: this was the start of the Bioref major.

Given that the courses are taught in English, the number of different nationalities represented during the different recruitments (ie more than thirty since the creation of the master in 2016), the nationality of the speakers (eg, Italian, German, Colombian, English, Russian, etc.) and the international collaborations that the master program has are proof of its international orientation.

## Socio-economic and industrial sectors concerned

The Bioref master's program is clearly oriented towards research and aims to train future experts who are passionate about this sector. This observation is all the more clear as there are currently very few "real" biorefineries as understood at the level of the EUROBIOREF consortium; that is to say, a complete integration of the process from all biomass categories to the final products. On the other hand, a multitude of “mini biorefineries” are currently developing, focusing on specific points in the process, while larger groups such as TOTAL, Arkema, Véolia, etc. are also turning to this sector. At a local level, a large site is developing around the sugar refinery and the ethanol plant initially present at Pomacle Bazancourt, with the arrival of the CEBB (European center for the bioeconomy and biorefinery). More globally, we should consider the production and treatment of seaweed on the coasts all over the world, the wood-based production specific to Scandinavian countries, the transformation of sugar cane in Brazil: it goes without saying, the future looks green!

## Professional opportunities

The Biorefinery master's degree is a new program (first cohort released in June / September 2017). Among the students who graduated from the Biorefinery Master 2 in June 2017, half went on to do a thesis and a third found a first job following the end-of-year internships. At the end of the thesis, graduates will be able to apply for positions such as: R & D engineer in industry, Head of research laboratory, Project engineer, Lecturer / CNRS researcher ...

The professional areas of bio-economy and biorefinery are new and thriving in today's business environment and are of course not limited to the list above. The graduates will be able to apply for a doctorate in the theme of the valorisation of biomass in the broad sense. As the diploma is multidisciplinary, the potential subjects are vast, as are the sources of funding.

## Research framework

A master member of the Graduate Study Program in Science for a changing planet:

- 22 laboratories
- 292 PhD students

An interdisciplinary training program going from a master's to a PhD level, including an international environment, mobility and thematic summer schools.

## Description and organisation of the major:

### Minimum requirements

To apply for the Bioref master's degree, you need a bac +4 level or equivalent in the fields of chemistry, chemical engineering, biochemistry or biology. As indicated above, the master is multidisciplinary.

### Pedagogical contents

The one-year training program is structured in courses, tutorials, projects and an internship. The first semester of the Biorefinery major provides courses covering a broad field ranging from the production of biomass itself to the pathways to obtaining molecules with high added value. Basics in catalysis and / or chemical engineering is a plus.

The training program is supported by the UCCS laboratory (Solid Catalysis and Chemistry Unit). Many international academic and industrial partners (Greece, Italy, Belgium, France, etc.) interact with the training course throughout teaching, site visits or in internship proposals.

| Unit title | Code | Module title | Hours number | ECTS Credits |
|---|---|---|---|---|
| **BIOREF L1** | | | | |
| Plant Biomass Production and valorisation | L1A | **LAND PLANTS: LIGNO-CELLULOSES, STARCH AND PROTEINS**<br>Structure (composition & organization) of plant cell walls constituting lignocellulosic biomass - Biological sources of variability in biomass composition - Introduction to protocols and techniques used in the com-positional analysis of lignocellulosic biomass.<br><br>The structure and metabolism of starch in plants, as well as basic methods for the analysis of starch samples including starch assaying methods,protein and phosphate contents determination, amylose/amylopectin ratioand amylopectin structure analysis, etc.).<br><br>Biomass production and recycling: Forage plant proteins :Recovery of plant proteins is a major concept in green biorefinery: are addressed in this lecture the plant sources, the recoverable protein fractions and protein processing, especially for feed and food production | 20 | 5 |
| | L1B | **AQUATIC BIOMASS**<br>Key challenges in microalgal and macroalgal biomass production: physiological requirements, cultivation and optimization. | 11 | |
| | L1C | **TYPE OF BIOREFINERIES, LINE PRODUCTS**<br>The different types and concepts of biorefineries are presented. Typical operations and material flows, economic, logistical, energy, social, ethical, etc. aspects are discussed to prepare students for the specialized study of each one, with an integrated view of the whole. | 4 | |
| **BIOREF L2** | | | | |
| Biomass pretreat- ment andthermal treatment | L2A | **CELLULOSIC BIOMASSPRETREATMENT: HYDROLYSE, FERMENTATION, CHEMICAL TREATMENT**<br>Introduction to the chemical and biotechnological methods employed forthe pretreatment and the enzymatic hydrolysis of the lignocellulosic bio-mass. In addition, the fermentation of sugars to chemicals, using bioethanol as an example, is presented. | 6 | 5 |
| | L2B | **LIGNIN PRETREAT-MENT: RADICAL AND CHEMICAL PRETREATMENTS**<br>Teaching on lignin: structure, composition, process to recover lignin, valorization of non-modified and modified lignin to fine chemicals, polymers, fuels, ... | 7 | |
| | L2C | **ALGAE FRACTION-ATION: TO PROTEIN, SUGARS,LIPIDS, FINE CHEMICALS** | - | |
| | L2D | **GASIFICATION OF BIOMASS – SYNGASPRODUCTION AND VALORISATION** | - | |
| | L2E | **BIOGAS FROM WASTE,RESIDUAL BIOMASS, ENVIRONMENTAL ISSUES**<br>Anaerobic digestion is a process of degradation of organic matter that generates a biogas (methane and carbon dioxide) and a digestate (organicresidue). Aspects such as degradation mechanism, reactors and issues ofthe process are reviewed, as well as the aspects of purification, valorization, environmental regulations and safety of the formed products. | 6 | |

| Unit title | Code | Module title | Hours number | ECTS Credits |
|---|---|---|---|---|
| **BIOREF L3** | | | | |
| Energy from biomass | L3A | **H2 PRODUCTION**<br>Hydrogen: first presenting some generalities, history, natural occurrence, and the production of hydrogen today. Then, the major part of the course concerns the production of hydrogen from bio-resources, including cur- rent researches. | 4 | 5 |
| | L3B | **BIOCARBURANT PRODUCTION**<br>While the electrification of transportation vehicles is currently progress- ing, the use of biofuels still has a large potential of reduction of green- house gases emissions. Through an introduction to combustion science and the importance of chain-branched kinetic mechanisms in combustion phenomena, the basics of fuel-engine adequacy will be exposed, for past and future engine technologies.<br><br>The course provides a comprehensive, up-to-date and multidisciplinary review of major industrial thermochemical processes for biofuels manufacturing. An emphasis is given to the reactors and processes for manufacturing of biofuels of second and third generation. Numerous aspects relevant to the technology, economic, environmental and social benefits of biofuels and reduced emissions of greenhouse gases are addressed in this course | 22 | |
| | L3C | **NON-CONVENTIONAL CARBURANT**<br>The different types and concepts of biorefineries are presented. Typical operations and material flows, economic, logistical, energy, social, ethical, etc. aspects are discussed to prepare students for the specialized study of each one, with an integrated view of the whole. | - | |
| **BIOREF L4** | | | | |
| Chemicals from biomass | L4A | **HOMOGENEOUSCATALYSIS FOR BIOMASS CONVERSION**<br>Basis of organometallic chemistry and homogeneous catalysis, with a combined overview of academic and industrial achievements and applications. Exemplification in the field of biomass upgrading is provided formajor classes of reactions and substrates<br><br>Homogeneous catalytic carbonylation and etherification reactions in thefield of biomass upgrading. Detailed mechanistics aspects for a better understanding of the concepts of homogeneous catalysis.<br><br>Overview of biosourced polymers, rather focused on synthesis / chemistry. High throughput characterization of catalysts using X-ray diffraction (XRD), X-ray Fluorescence (XRF), Raman and InfraRed spectrometers and Inductively coupled plasma- optical emission spectrometry (ICP- OES). | 24 | 10 |
| | L4B | **HETEROGENEOUSCATALYSIS FOR BIOMASS CONVERSION**<br>Basis of catalysis - chromatography basis- characterization techniques (BET/XPS/XRD/NMR/…)<br><br>Catalytic biomass valorization (lignocellulosic and oleaginous)- currents and future process applied in biorefineries<br>Introduction to the catalytic valorization of carbohydrates. The first part covers the chemistry of sugars including structure, stereochemistry and chemical activity of sugars. During the second | 22 | |

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| | | part of the course the introduction to the catalytic valorization of different carbohydrates by heterogeneous catalysis is given. | | |
| | L4C | **BIOTECHNOLOGY FORBIOMASS CONVERSION**<br>Basis of microbial physiology, fermentation processes and methods employed to analyze, design and modify metabolic pathways to improve a microbial biocatalyst in order to understand the basic engineering concepts underlying the biocatalytic conversion of raw materials to productsincluding fuels and chemicals.<br><br>Theoretical and applied concepts on the use of enzymes in homogeneous or heterogeneous catalysis and the implication of enzymatic catalysis in the concept of hybrid catalysis (combination with chemical catalysis). | 21 | |
| **BIOREF L5** | | | | |
| Language | L5 | **ENGLISH**<br>The English course with Bioref aims at mastering Academic English as used in universities and scientific laboratories, with a focus on scientific audio and written documents plus class discussion on extra topics related to science. Internet sources such as Ted Talks are used to trigger discus- sion about the impact of technological innovations on today's world. A workbook of activities and exercises is used. | 48 | 5 |

### Teaching team

The teaching team is mainly constituted of teachers from Centrale Lille, the University of Lille and CNRS researchers. When it comes to specific areas, experts from other institutions (Italy, Poitiers, UTT, etc.) may intervene.

### Competencies

The gradual replacement of processes involving fossil molecules by green synthons involves the creation of biorefineries. The implementation of these new entities requires knowledge of the local environment, of the nature and potential of the different biomasses available, of crop rotation, etc. The aim of the Biorefinery master is therefore to provide students with the skills necessary to overcome the new challenges of the 21st century:

- project management which will be applied both during the master thesis but also during bibliographic projects and mini projects proposed in progress.
- fluency in English, which is the official language of the master program, both during the lessons but also during the various defenses and exams.
- teamwork, amplified by the fact that students are immersed throughout the year in an international and multicultural environment both by the diversity of colleagues, professors and industry involved in the program.

All these elements should allow students to blend easily into the world of the bioeconomy and into the biorefineries of tomorrow.