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Greening Energy Market and Finance
Erasmus Mundus Joint Master
GrEnFIn-EMJM

MODULES HANDBOOK

ERASMUS MUNDUS JOINT MASTER PROGRAMME

Greening Energy Market and Finance (GrEnFIn)

offered by

Alma Mater Studiorum - Università di Bologna (UNIBO),
Ludwing Maximilian University (LMU),
Université Paris-Dauphine (UPD)

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LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

Dauphine | PSL UNIVERSITÉ PARIS

https://site.unibo.it/grenfin-emjm/en
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Key Details

Numbering scheme

The numbering scheme for modules is as follows:

[HEI]-[course number],

where [HEI] identifies where the module is taught (UNIBO, LMU, UPD) and [course-number] is a continuous number per location.

Workload

In accordance with the European Credit Transfer and Accumulation System (ECTS), one ECTS credit corresponds to a workload of 25 to 30 hours. Due to variations in the duration of semesters in France, Germany, and Italy, as well as differences in module types and depth, individual workloads may differ. The workload mentioned in the module descriptions below is calculated assuming 25 hours for consistency and reflects the typical workload associated with these modules.

Delivery method

While all courses are initially designed for face-to-face delivery, adjustments to the mode of delivery may be made in response to external constraints, as agreed upon with the partner Higher Education Institutions (HEIs).

Assessments

The majority of modules conclude with an examination. In cases where the examination type is not predefined in the module description, the examiner must specify it before the semester commencement. Further information on examinations, including their duration and announcement procedures, will be detailed on the dedicated website.

Teaching approaches

The choice of teaching methods is contingent upon the nature of the course:

- “Lecture” for courses of the lecture format and seminars delivered by academics or guest speakers.
- “Problem/Case Studies-based learning” for tutorials, exercise-oriented sessions, lectures by professionals during intensive programs and winter/summer schools.
- “Seminar” for presentations prepared by students.
- “Directed discussion” for in-class discussions of presented material, including flipped classes.
- “Lab” for IT lab session, including Advanced Stats lab, Python coding conducted by the students/teachers/tutors and under supervision.
- “Research” for the Master thesis and internships/Raship

Teachers may vary from the indicated teaching methods based on personal preferences.

Period of teaching

Different Colors identify the teaching period:

light gray=first semester
light green=second semester
medium green=third semester
dark green=fourth semester

Program learning outcomes

Students will acquire quantitative tools applied to economic-financial sustainability issues as well as knowledge of fundamental concepts related to renewable energy technologies, along with the modeling and development of predictive approach to simulate the impact of natural variables (such as meteorological/climatic variables) using simulation tools and machine-learning approaches. The implementation of these models includes laboratory activities aimed at acquiring skills in major programming languages, such as Python™. Students will also gain advanced knowledge in the area related to their selected curriculum. The specializations include "Renewable Technologies," "Environmental Finance," or "Business & Climate Science," allowing for an in-depth study in the engineering, financial, or economic-business domains.

The students in the GrEnFIn program will develop the ability to analyze and solve both concrete and abstract problems within their specialized field of interest. They will acquire crucial skills for scientific work and professionally oriented activities, including the application of mathematical and technical methods to engineering, finance, and economics challenges. Moreover, they will be adept at critically discussing scientific topics and conducting research projects that involve investigating applied problems. Furthermore, the students will obtain language and presentation skills (English, possibly French, German and Italian) and practice geographical mobility.

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GrEnFIn curriculum in Renewable Technologies

First Semester. All modules of the first semester are offered by UPD in the UK campus (London). Compulsory modules sum up to 15 ECTS while 15 ECTS must be chosen among the electives.

No.	COMPULSORY MODULE	ECTS	GRADED
UPD-01	STOCHASTIC CALCULUS	3	YES
UPD-03	FINANCIAL MODELING with Python	3	YES
UPD-04	PORTFOLIO MANAGEMENT	6	YES
UPD-05	MICROECONOMICS and ENVIRONMENT	3	YES
No.	**ELECTIVE MODULE**	**ECTS**	**GRADED**
UPD-02	FINANCIAL STATEMENT ANALYSIS	3	YES
UPD-06	MACROECONOMICS	3	YES
UPD-07	TIME SERIES ECONOMETRICS	6	YES
UPD-08	DERIVATIVE INSTRUMENTS	3	YES

Second and Third Semesters. All modules are offered by UNIBO except for the winter/summer school which are also offered by LMU and UPD. Light green identifies the second semester while medium green the third one. Compulsory modules sum up to 48 ECTS credits and students must choose from elective courses further 12 Credits. Students must choose just one winter/summer school.

No.	COMPULSORY MODULE	ECTS	GRADED
UNIBO-05	EARTH SYSTEM AND CLIMATE CHANGE	6	YES
UNIBO-04	FINANCIAL MARKETS AND CLIMATE CHANGE: PRICING/HEDGING AND ASSET MANAGEMENT-MATHEMATICAL FINANCE, ASSET PRICING AND DERIVATIVES	6	YES
UNIBO-06	SMART GRIDS FOR SMART CITIES	6	YES
UNIBO-07	PYTHON CODING AND DATA SCIENCE	6	YES
UNIBO-08	INTERNATIONAL LAW AND SUSTAINABILITY	6	YES
UNIBO-09	CREDIT AND WEATHER DERIVATIVES	6	YES
UNIBO-10	SOLAR&WIND ENERGY AND STORAGE SYSTEMS	6	YES
UNIBO-11	MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE	6	YES
No.	**ELECTIVE MODULE**	**ECTS**	**GRADED**
UNIBO-14	HYDRAULIC AND BIOENERGY (C.I.)-MARINE RENEWABLE ENERGY-	6	YES

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	BIOENERGY, HYDROGEN AND HEAT RECOVERY SYSTEMS		
UNIBO-15	STATISTICS OF FINANCIAL MARKETS	6	YES
UNIBO-16	ECONOMICS OF FINANCIAL MARKET AND SUSTAINABLE PERSPECTIVES	6	YES
UNIBO-17	ECONOMETRICS FOR FINANCIAL MARKETS	6	YES
	ADVANCED RISK AND PORTFOLIO MANAGEMENT	6-9	
UNIBO-18	INTENSIVE PROGRAMME	6	YES
UNIBO-19	GrEnFIn-SUMMER SCHOOL AND TRAINING	6	YES
LMU-12	GrEnFIn-WINTER SCHOOL	6	YES
UPD-24	GrEnFIn-SUMMER SCHOOL	6	YES

Fourth Semester. The modules of the fourth semester are offered by LMU. The modules are compulsory and consist of the final examination and the internship/RAship. Students can choose to elaborate an industrial research project within a company (internship) or a more theoretical one within a HEI/research institute (RAship).

No.	COMPULSORY MODULE	ECTS	GRADED
LMU-10	INTERNSHIP/RAship	6	NO
LMU-11	FINAL EXAMINATION	27	YES

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GrEnFIn curriculum in Environmental Finance

First and Second Semesters. All modules are offered by LMU except for the summer/winter school which are also offered by UNIBO and UPD. Light gray identifies the first semester while light green the second one. Compulsory modules sum up to 51 ECTS credits and students must choose from elective courses 9-12 ECTS, including one summer/winter school.

No.	COMPULSORY MODULE	ECTS	GRADED
LMU-01	STOCHASTIC CALCULUS AND ARBITRAGE THEORY IN CONTINUOUS TIME	9	YES
LMU-03	ADVANCED TOPICS IN FINANCIAL MATHEMATICS B	6	YES
LMU-04	CLIMATE SYSTEM AND CLIMATE CHANGE (STATISTICAL INFERENCE)	9	YES
LMU-09	NUMERICAL METHODS IN FINANCIAL MATHEMATICS	9	YES
LMU-07	FIXED INCOME MARKETS AND CREDIT DERIVATIVES	9	YES
LMU-08	QUANTITATIVE RISK MANAGEMENT	9	YES
No.	**ELECTIVE MODULE**	**ECTS**	**GRADED**
LMU-12	GrEnFIn-WINTER SCHOOL	6	YES
LMU-05	CLIMATE-RELATED RISK AND COMMODITY MARKET II (Elective Topics in Business Administration-Theory I)	6	YES
LMU-15	ECONOMETRICS	6	YES
LMU-02	ADVANCED TOPIC IN FINANCIAL MATHEMATICS C	3	YES
LMU-14	SEMINAR	3	YES
LMU-13	STATISTICAL METHODS FOR FINANCIAL MATHEMATICS	6	YES
LMU-06	ADVANCED TOPIC IN COMPUTER AND DATA SCIENCE B	6	YES
UPD-24	GrEnFIn-SUMMER SCHOOL	6	YES
UNIBO-19	GrEnFIn-SUMMER SCHOOL AND TRAINING	6	YES

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Third Semester. The modules of the third semester are offered by UPD (Paris). The compulsory modules count for 18 ECTS while further 12 ECTS must be chosen among the electives.

No.	COMPULSORY MODULE	ECTS	GRADED
UPD-20	ENERGY AND ENVIRONMENTAL ECONOMICS	6	YES
UPD-11	GREEN FINANCE: MARKET FINANCE AND PROJECT FINANCING	6	YES
UPD-15	PYTHON-MACHINE LEARNING	3	YES
UPD-09	CORPORATE LAW AND BUSINESS ETHICS	3	YES
No.	**ELECTIVE MODULE**	**ECTS**	**GRADED**
UPD-23	CORPORATE STRATEGY	3	YES
UPD-18	ADVANCED METHODS FOR RISK MANAGEMENT	6	YES
UPD-14	MACROECONOMICS OF MARKET PARTICIPANT	3	YES
UPD-19	ECONOMY OF CLIMATE CHANGE	6	YES
UPD-21	BEHAVIORAL FINANCE	3	YES
UPD-16	SAS/R/SQL DATA ANALYSIS, DATA MODELING	3	YES
UPD-22	INVESTING IN FINANCIAL MARKET	3	YES
UPD-10	LEADERSHIP IN FINANCE	6	YES
UPD-17	EMPIRICAL MODELING OF ELECTRICITY AND GAS MARKETS	6	YES

Fourth Semester. The modules of the fourth semester are offered by UNIBO. The modules are compulsory and consists of the final examination and the internship/RAship. Students can choose to elaborate an industrial research project within a company (internship) or a more theoretical one within a HEI/research institute (RAship).

No.	COMPULSORY MODULE	ECTS	GRADED
UNIBO-12	INTERNSHIP/RAship (UNIBO)	12	NO
UNIBO-13	FINAL EXAMINATION (LMU)	18	YES

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GrEnFIn curriculum in Climate&Business

First Semester. All modules are offered by UNIBO. Compulsory modules sum up to 30 ECTS.

No.	COMPULSORY MODULE	ECTS	GRADED
UNIBO-01	RISK MODELING AND PROBABILITY	12	YES
UNIBO-02	CLIMATE AND ENERGY ECONOMICS	12	YES
UNIBO-03	FINANCIAL MARKET AND CLIMATE CHANGE: PRICING/HEDGING AND ASSET MANAGEMENT-ASSET MANAGEMENT AND TRANSITION RISK	6	YES

Second Semester. All modules are offered by LMU except for the summer/winter school which are offered by UNIBO and UPD. Compulsory modules sum up to 27 ECTS while further 3-6 ECTS must be selected among the elective. The winter/summer school can be selected just one time.

No.	COMPULSORY MODULE	ECTS	GRADED
LMU-07	FIXED INCOME MARKETS AND CREDIT DERIVATIVES	9	YES
LMU-08	QUANTITATIVE RISK MANAGEMENT	9	YES
LMU-09	NUMERICAL METHODS IN FINANCIAL MATHEMATICS	9	YES
No.	**ELECTIVE MODULE**	**ECTS**	**GRADED**
UNIBO-19	GrEnFIn-SUMMER SCHOOL AND TRAINING	6	YES
UPD-24	GrEnFIn-SUMMER SCHOOL	6	YES
LMU-13	STATISTICAL MODELS FOR FINANCIAL MATHEMATICS	6	YES
LMU-14	SEMINAR	3	YES

Third and Fourth Semesters. All modules are offered by UPD (Paris) except for the summer/winter school which are also offered by UNIBO and LMU. Medium green identifies the third semester while dark green the forth one. Compulsory modules sum up to 42 ECTS credits and students must choose from elective further 18 ECTS. Courses, including one summer/winter school.

No.	COMPULSORY MODULE	ECTS	GRADED
UPD-09	CORPORATE LAW AND BUSINESS ETHICS	3	YES
UPD-20	ENERGY AND ENVIRONMENTAL ECONOMICS	6	YES
UPD-11	GREEN FINANCE: MARKET FINANCE AND PROJECT FINANCING	6	YES

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UPD-19	ECONOMY OF CLIMATE CHANGE	6	YES
UPD-12	INTERNSHIP/RAship	6	NO
UPD-13	FINAL EXAMINATION	24	YES
No.	**ELECTIVE MODULE**	**ECTS**	**GRADED**
UNIBO-19	GrEnFIn-SUMMER SCHOOL AND TRAINING	6	YES
LMU-12	GrEnFIn-WINTER SCHOOL	6	YES
UPD-24	GrEnFIn-SUMMER SCHOOL	6	YES
UPD-18	ECONOMICS OF ENERGY AND ENVIRONMENT I	3	YES
UPD-16	SAS/R/SQL DATA ANALYSIS, DATA MODELING	3	YES
UPD-21	BEHAVIORAL FINANCE	3	YES
UPD-10	LEADERSHIP IN FINANCE	6	YES
UPD-14	MACROECONOMICS OF MARKET PARTICIPANTS	3	YES
UPD-18	ADVANCED METHODS FOR RISK MANAGEMENT	6	YES
UPD-22	INVESTING ON FINANCIAL MARKETS	3	YES
UPD-23	CORPORATE STRATEGY	3	YES
UPD-19	ECONOMY OF CLIMATE CHANGE	6	YES

MODULES' DETAILS

UNIBO

RISK MODELING AND PROBABILITY (UNIBO-01)				
Frequency Winter Semester	**Duration** Semester	**Second Semester**	**Credits** 12	**Workload** 300h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 80%, Problem-learning 20%		**Language** English	**Contact hours per week** 6	
CONTENT				

Axiomatic definition of probability. Uniform probability spaces. Counting methods: replacement, ordering. Conditional probability. Independence for events. The law of total probability. Bayes' rule.
Discrete random variables. Independence for random variables. Joint, marginal, and conditional densities. Common random variables and their interpretation: Bernoulli, dicrete uniform, binomial, hypergeometric, geometric, Poisson, Pascal.
Expectation of dicrete random variables. Variance and its properties. Expectation and variance of common random variables. Covariance and correlation. Variance of a sum. Null correlation and independence. Linear prediction.
Conditional expectation and its properties. Conditional Variance. Sigma-algebras, Continuous Random variables. The Uniform and Exponential distributions. Distribution functions and densities.
Marginal, joint and conditional densities. Gamma, Normal and Cauchy distribution. Derived Distributions: monotonic and general case. Conditional Expectation. Law of total expectation. Markov and Chebishev Inequalities.
Convergence of Random Variables. The Weak and Strong Laws of Large Numbers. Characteristic Functions and their properties. CF of a sum. CF of common random variables. The Central Limit Theorem.

Construction of Brownian Motion and Wiener measure. Markovian, martingale and sample path properties of Brownian motion.
Continuous local martingales. Quadratic variation. Simple integrands and the elementary stochastic integral. Ito isometry.
Stochastic integration with respect to continuous local martingales. Ito's formula.
Equivalent changes of probability. Stochastic exponentials. Girsanov's theorem.
Brownian filtrations and the martingale representation theorem. Stochastic differential

equations driven by Brownian motion. **Connections with partial differential equations**. Cauchy problems and the Feynman-Kac representation.
LEARNING OUTCOMES
At the end of the course the student has good knowledge of probability theory of discrete and continuous random variables. Particular attention is paid to the theory of stochastic processes. The student masters the main techniques of stochastic calculus applied to finance, such as stochastic differential and integral domain and change of measure techniques.
FINAL EXAM
Graded Module Written
Responsible Prof. Paolo Guasoni

CLIMATE AND ENERGY ECONOMICS (UNIBO-02)				
Frequency Winter Semester	**Duration** Semester	**Second Semester**	**Credits** 12	**Workload** 300h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 70%, Problem-learning 20%, Direct discussion 10%		**Language** English	**Contact hours per week** 6	
CONTENT				
The course is composed by two modules, the first about climate economics while the second about energy economics. The module will cover the following topics: Climate change: the physical basis and impacts, Carbon emission drivers; abatement strategies; investment needs, Transition dynamics and socio-economic impacts, Climate-related macro-financial risks; physical/financial asset stranding, Mitigation policies: carbon pricing and permit markets, Sustainable finance policy-making; central banks and financial supervisors, Climate economic modelling: the DICE model, IAMS and CGE models, Neoclassical transition modelling approaches, Complexity-driven transition modelling approaches, Production and financial networks. The second module will provide an overview on interactions between commodity and energy markets and climate policy, with an interdisciplinary but primarily economic				

perspective. Markets covered will include fossil resources (coal, oil, gas); electricity; emission permit markets.
LEARNING OUTCOMES
The module will offer students an interdisciplinary perspective on climate-related economic and financial risks and on appropriate societal responses to mitigate them. At the end of the course students will have developed a solid knowledge of the academic literature and policy debate on how climate change and the decarbonization process might affect economic activity, and vice versa.
FINAL EXAM
Graded Module Written exam, a take-home essay and two pieces of assessed coursework
Responsible Profs Emanuele Campiglio, Niko Samuli Jakkola

FINANCIAL MARKET AND CLIMATE CHANGE: PRICING/HEDGING AND ASSET MANAGEMENT-ASSET MANAGEMENT AND TRANSITION RISK (UNIBO-03)				
Frequency Winter Semester	**Duration** Half Semester	**Second Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 80%, Problem-learning 20%		**Language** English	**Contact hours per week** 6	

CONTENT

- Capital allocation to risky assets
- Capital Asset Pricing Model, Arbitrage Pricing Theory and multifactor models
- Climate and finance: Physical risk and transition risk
- ESG-driven investment
- Climate-driven investment (decarbonization of a portfolio; green financial assets)
- Portfolio performance evaluation (traditional and sustainability-corrected measures)

LEARNING OUTCOMES
At the end of the course students will be able to provide a financial service of managing assets by means of financial instruments with the aim of increasing the invested assets. Investment opportunities including government financing through sovereign bonds, private sector financing through equity or bond purchases, and financing infrastructure needs, with

the aim of generating a return that is shared between the asset manager as remuneration and the investor as their return, will be matter of discussion.
FINAL EXAM
Graded Module Written exam
Responsible Prof. Mascia Bedendo

FINANCIAL MARKETS AND CLIMATE CHANGE: PRICING/HEDGING AND ASSET MANAGEMENT-MATHEMATICAL FINANCE, ASSET PRICING AND DERIVATIVES (UNIBO-04)				
Frequency Summer Semester	**Duration** Half-Semester	**Second Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 80%, Problem-learning 20%		**Language** English	**Contact hours per week** 6	
CONTENT				
Stochastic calculus principles: stochastic process, discrete and continuous martingale, diffusion and Ito's process, Markov 's process, exponential martingale and probability changing, Girsanov's theorem, stochastic integration and Ito's lemma, SDE and PDE, Kolmogorov's PDE, Feynman-Kac's theorem; **Plain vanilla contingent claims's pricing and hedging**: forward and future, european and american options, pricing and hedging by arbitrage, self-financing portfolio, CRR's model, BS's model, volatility analysis and smile effect, arbitrage model for Ito's market, market premium and market numeraire, BS formula for exchange options, complete and incomplete markets; **Domestic-Foreign arbitrage and exotic options**: Black's model, quantos and compos, digital options, regular and reverse barrier options, loockback options and options on running minimum (maximum) of underlying asset, Weather Derivatives; **Thematic Area** to be addressed to specific Frontier Topics of interest of the educational path.				
LEARNING OUTCOMES				
At the end of the course the student masters the main concepts of financial mathematics. The course will cover the stochastic dynamics of asset prices assumed under the efficient				

market theory, the concept of arbitrage-free pricing and replicating strategies, leading to the PDE approach to pricing.
FINAL EXAM
Graded Module Written (compulsory), Oral (under request)
Responsible Prof. Silvia Romagnoli (UNIBO)

EARTH SYSTEM AND CLIMATE CHANGE (UNIBO-05)				
Frequency Summer Semester	**Duration** Half-Semester	**Second Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture		**Language** English	**Contact hours per week** 6	
CONTENT				
The purpose of this course is to explore the basic physics of the Earth climate system and its forcing, evaluating the role of each component on climate and its variability. A deep learning of the evolution of the Earth climate is given to understand the ongoing climate change. The students will learn to navigate the intricacies of the earth system, learning the role of atmospheric and ocean circulations, water cycle, greenhouse gases and aerosol, energy balance and solar heating variability, and the complex nature of climate feedback. Students will also learn the effects of natural and anthropogenic forcing on climate, to comprehend the state-of-the-art knowledge on future climatic scenarios.				
LEARNING OUTCOMES				
Students will acquire knowledge of the various components of the Earth climatic system and the temporal scales of their interactions. They will acquire an understanding of climate change through worked examples. Outputs of numerical models used for climate projections will be used to illustrate how climate change evolves. Students will be able to assess trends of the climate system.				
FINAL EXAM				
Graded Module Oral exam				
Responsible Profs Felice Natale Carrassi, Francesco Barbano (UNIBO)				

SMART GRIDS FOR SMART CITIES (UNIBO-06)				
Frequency Summer Semester	**Duration** One Semester	**Second Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture		**Language** English	**Contact hours per week** 6	

CONTENT

The course is divided into two parts (one given by Prof. C.A. Nucci and the other given by Prof. S. Lilla):

1. Structure of the electrical systems and its evolution from the origins to the modern smart grid. Main key technical issues relevant to the operation and control of modern electric power systems able to supply smart cities including energy communities and ground transportation (by Prof. S. Lilla).

2. Renewables integration in the Electric Power System and relevant technical issues. Smart grids: main technical features. Smart Cities: definition and relevant sub-systems. The EU Mission 'Climate Neutral and Smart Cities". The Smart Grid is the main enabler for the implementation of the Smart City paradigm. Energy Communities (by Prof. C.A. Nucci).

LEARNING OUTCOMES

The module provides the technical basics for understanding the main technical requirements for accomplishing the paradigm of climate neutral cities and the concept and functions of energy communities. At the end of the course students are able to understand the role played by energy communities in a climate neutral city, with particular focus on the requirements posed by the EU Clean Energy Package and own the fundamentals of the economy of electric power systems, of electricity tariffication and of international and national standards relevant to the electric energy sector.

FINAL EXAM

Graded Module
Oral exam

Responsible
Profs Carlo Alberto Nucci, Stefano Lilla (UNIBO)

PYTHON CODING AND DATA SCIENCE (UNIBO-07)				
Frequency Summer Semester	**Duration** One Semester	**Second Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lab		**Language** English	**Contact hours per week** 6	

CONTENT

Basic Python: Using the Python Interpreter, An Informal Introduction to Python, Control Flow Tools, Data Structures, Modules, Input and Output, Errors and Exceptions, Classes, Brief Tour of the Standard Library, Virtual Environments and Packages

NumPy: Array objects (The N-dimensional array (ndarray), Scalars, Data type objects (dtype), Indexing routines, Iterating Over Arrays, Standard array subclasses, Masked arrays, The array interface protocol, Datetimes and Timedeltas), Constants, Routines (Array creation routines, Array manipulation routines, Binary operations, String operations, Mathematical functions with automatic domain, Floating point error handling, Functional programming, NumPy-specific help functions, Input and output, Linear algebra (numpy.linalg), Logic functions, Masked array operations, Mathematical functions, Miscellaneous routines, Random sampling (numpy.random), Set routines, Sorting, searching, and counting Statistics)

SciPy: Introduction, Special functions (scipy.special), Integration (scipy.integrate), Optimization (scipy.optimize), Interpolation (scipy.interpolate), Linear Algebra (scipy.linalg), Statistics (scipy.stats).

pandas: basics (Object creation, Viewing data, Selection, Missing data, Operations, Merge, Grouping, Reshaping, Time series, Categoricals, Plotting, Getting data in/out, Gotchas), Intro to data structures, Essential basic functionality, IO tools (text, CSV, HDF5, …), Indexing and selecting data, MultiIndex / advanced indexing, Merge, join, concatenate and compare, Reshaping and pivot tables, Working with text data, Working with missing data, Categorical data, Computational tools, Group by: split-apply-combine

Elements of matplotlib

LEARNING OUTCOMES

The focus of the course is on Phython coding & Data Science which have gained great popularity in the last few years, especially in the field of financial applications. Students will acquire a good knowledge of Coding with a special focus on financial application and frontier topics of green finance.

FINAL EXAM
Graded Module Written exam (and assignments)
Responsible Prof Pietro Rossi (UNIBO)

INTERNATIONAL LAW AND SUSTAINABILITY (UNIBO-08)				
Frequency Summer Semester	**Duration** Half-Semester	**Second Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture		**Language** English	**Contact hours per week** 6	
CONTENT				

The course addresses the international legal and institutional framework on the protection of the environment.

Throughout the course, the law governing the protection and management of freshwater resources will be taken as a case study to give relevant examples on the functioning of international environmental law.

First, international environmental law will be presented as the outcome of an ongoing social development within the International Community started with the 1972 Stockholm Conference on Human Environment.

Second, rules and principles regulating the management of environmental resources will be presented both in their substantive and procedural nature, stressing the interplay between these two levels in assuring a sound management of environmental risks and resources.

Third, the interplay between international environmental law and other fields of international law will be tackled. A specific focus will be made on the relationship with human rights law, international economic law and the law of armed conflicts.

Last, specific substantive areas of international environmental law will be outlined. In particular, seminars will be delivered on the protection of biodiversity, the protection of marine environment and climate change.

LEARNING OUTCOMES
At the end of the course students have a broader and deeper legal knowledge of the contemporary legal issues related to market regulation, and the consequences of economic agents' behaviour, both under the international and the national legal framework.
FINAL EXAM
Graded Module Oral exam
Responsible Prof Attila Massimiliano Tanzi (UNIBO)

CREDIT AND WEATHER DERIVATIVES (UNIBO-09)				
Frequency Winter Semester	**Duration** Half-Semester	**Second Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 40%, Lab 30%, Problem-learning 30%		**Language** English	**Contact hours per week** 6	
CONTENT				
The term structure of interest rates and bond prices, Default-free bonds vs defaultable bonds. Green bonds vs traditional bonds, The pletora of credit spreads and The puzzle of green premiums, The basic of credit derivatives. The basic of weather derivatives, Single name credit derivatives: ASW and CDS. The CDS-bond basis, Single name credit models: structural and intensity-based models, Multi-name credit derivatives: credit indexes, first to default swaps. CDS index: Itaxx and CDX. Securitization: CDOs and ABS, Green Securitization, Multi-name credit models: copula functions, Pricing Weather derivatives: models and assumptions. A case study: pricing options with payouts depending on temperature.				
LEARNING OUTCOMES				
At the end of the course the student knows how to transfer credit and climate risk by means of swap arrangements (asset swaps and TRORS), and with credit/weather derivatives. The student knows the analysis developed both on a single name basis (CDS) and on a multiname basis (CDO, CDX, iTraxx). The analysis is extended to large CDO, ABS and ABX.				
FINAL EXAM				
Graded Module				

Written exam (compulsory), Oral exam (under request)
Responsible Prof Marco Di Francesco (UNIBO)

SOLAR&WIND ENERGY AND STORAGE SYSTEMS (UNIBO-10)				
Frequency Winter Semester	**Duration** One Semester	**Second Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 70%, Direct discussion 30%		**Language** English	**Contact hours per week** 6	
CONTENT				
Solar Energy. General information concerning solar energy. Solar systems for production of thermal energy at low temperatures. Concentrated solar power. Solar cooling. Photovoltaic energy. Solar panels and plants. Estimation of the capacity of a solar plant. Hybrid thermal systems for heating and cooling. Wind energy. Analysis of the forces governing the wind flows. Wind systems: analysis of the exploitation of a site for wind energy production. Horizontal and vertical axis wind turbines, Estimation of the wind energy economic value. “Energy sustainability” by a techno-economic point of view with a focus on energy storage/conversion technologies. The key role played by the electrochemical systems, like batteries, supercapacitors and fuel cells, is discussed.				
LEARNING OUTCOMES				
The course summarizes the technological state-of-the-art in the field of Solar and wind energy: i) Solar systems for production of thermal energy at low temperature, concentrated solar power, solar cooling. Hybrid thermal systems for heating and cooling.ii) Wind systems: analysis of the exploitation of a site for wind energy production, Horizontal and vertical axis wind turbines, Estimation of the wind energy economic value. After completion of the course the students should (i) gain general competence related to the main technologies based on solar energy and wind energy and their potential in future energy supply; (ii) make an economic analysis of the expected value of energy obtained by solar or wind exploitation. Concerning the storage systems, students acquire i) a comprehensive overview of the different energy storage/conversion technologies for renewable energy plants and e-mobility as long as a basic and technological knowledge of the most advanced materials for				

energy storage/conversion systems such as lithium batteries, supercapacitors and fuel cells ii) learn the fundamentals of cell electrochemistry, materials characteristics and main challenges related to the manufacturing process iv) classify the possible cell chemistry and technology in relation to the application range and system sustainability.
FINAL EXAM
Graded Module Oral exam
Responsible Profs Eugenia Rossi Di Schio, Francesca Soavi (UNIBO)

MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE (UNIBO-11)				
Frequency Winter Semester	**Duration** One Semester	**Second Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 30%, Lab 70%		**Language** English	**Contact hours per week** 6	
CONTENT				
Introduction to ML. What is ML: a shift from knowledge to data, Kind of problems, supervised versus unsupervised, regression vs classification, Data pipeline, Python Basics **Data Preprocessing**. Data Normalizzation, Categorical variables: ordinal and non-ordinal, Outliers, Feature Engineering, Dimensionality reduction:PCA, Examples in python: sklearn **Linear Regression**. Estimating the coefficients: Least Square Method & maximum likehood, Performance metrics, Interpreting the coefficients, The problem of Collinearity, Selecting the relevant variables: Lasso/Ridge regression, Kernel Regression, Pyhton Hand-on **Logistic Regression**. Problem Definition, Estimating the coefficients: gradient descent, Classification Metrics (Precision, Recall, F-beta score, Area Under tre ROC curve), Interpreting the coefficients, Generalized linear model: Poisson regression, Multilabel case, Python hands-on **Evaluate a Model**. Cross-validation & hyper parameter tuning, Bias Variance trade-off, Simple cross-validation, N-fold cross-validation, Python hands-on **Tree Based Method**. Simple Cart for regression and classification, Ensample methods: Random Forest, Boosting methods, Python hands-on **Unsupervised learning**. Problems, K-means, Density-Based Model: DBSCAN, Remove outliers using unsupervised methods, Python Hands-on				

LEARNING OUTCOMES
At the end of the course students will have a good knowledge of machine learning and Artificial Intelligence. They will be able to apply these techniques to problems related to climate change and sustainability.
FINAL EXAM
Graded Module Written exam
Responsible Profs Matteo Amabili, Antonio Petruccelli (Leithà-Unipol)

INTERNSHIP/RAship (UNIBO-12)				
Frequency Summer Semester	**Duration** 3 Months	**Second Semester**	**Credits** 12	**Workload** 300h
MODULE STRUCTURE AND LANGUAGE				
Type Research		**Language** English	**Contact hours per week** TBD	
CONTENT				
In preparation for the final examination, the student performs activities in the field of sustainability, to be carried out at HEIs, research institutes, and companies.				
LEARNING OUTCOMES				
The student carries out specific work, under the supervision of an external tutor, aimed at refining his/her learning skills and professional education.				
FINAL EXAM				
Not Graded Module Final Report				
Responsible Prof. Silvia Romagnoli (UNIBO)				

FINAL EXAMINATION (UNIBO-13)				
Frequency Summer Semester	**Duration** -	**Second Semester**	**Credits** 18	**Workload** 450h
MODULE STRUCTURE AND LANGUAGE				
Type Research		**Language** English	**Contact hours per week** TBD	
CONTENT				
The preparation of the final examination is devoted to activities of higher formation, in the field of industrial/scientific research in sustainability fields, to be carried out in connection with the internship/RAship experience. An academic tutor acts as supervisor as well as the external supervisor of the internship/RAship. The final thesis is written in coherence with the rule reported on the GrEnFIn-EMJM website. Discussion of the research project and the related fields.				
LEARNING OUTCOMES				
The student carries out specific work, under the supervision of an external tutor, aimed at refining his/her learning skills and professional education.				
FINAL EXAM				
Graded Module Final Thesis				
Responsible TBD				

HYDRAULIC AND BIOENERGY (C.I.)- MARINE RENEWABLE ENERGY- BIOENERGY, HYDROGEN AND HEAT RECOVERY SYSTEMS (UNIBO) (UNIBO-14)				
Frequency Winter Semester	**Duration** One Semester	**Second Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 80%, Direct discussion 20%		**Language** English	**Contact hours per week** 6	
CONTENT				
Marine renewable energy: sources (wind, wave, tide) and variability. Type of marine renewable energy converters. Fixed and floating wind turbines. Wave energy converters: classification, main existing converters, barriers to commercialization, technological				

challenges. Environmental impact of MRE devices. Costs of MRE devices. Optimal mixing of MRE. Criteria and tool. Case studies. Multi-use marine areas. Integration of different economic activities: MRE, aquaculture, tourism, maritime hubs. Case studies. Re-purposing of O&G platforms.

Hydrogen. Introduction to the use of hydrogen as energy vector and fuel, Hydrogen production: electrolysis and steam reforming, Reconversion of hydrogen energy into electricity: fuel cells and combustion engines, Blends of hydrogen and natural gas as fuel in gas turbine power cycle: overview of gas turbine working principle; blend's properties varying hydrogen fraction, technical issues.

WHR. Heat recovery systems: overview (temperature levels, heat sources, conversion technologies), Organic Rankine cycle power system: architecture and working principle; thermodynamic analysis and performance, Overview of other technologies for the conversion of thermal energy into electricity: stirling engines, thermoelectric generators.

Bioenergy. Biomass energy: types of biomass, distribution, energy density of biomass and properties, Biogas production (gassification, pyrolysis, anaerobic digestion), Biomass reconversion into electricity: direct combustion, ICE, GT

LEARNING OUTCOMES

Students acquire the ability to assess marine renewable energy potential and to conceptually design energy devices. They will be able to assess marine energy potential (wind, waves, tides, currents, etc.) and will have knowledge about devices for marine energy harvesting and technological challenges, and assessment of Environmental, social and economic impacts. Moreover the course provides the student with knowledge and understanding about: Biomass and alternative fuels for energy application: production, treatment and storage, thermochemical conversion, environmental and economic aspects; Hydrogen for energy and transport applications: characteristics, production, gas-to-power (G2P) and power-to-gas (P2G) systems, technologies for upgrading fuels (synthetic methane), fields of application, integration into the existing infrastructure; Heat recovery systems: cycles and working principle of the main heat-to-power (H2P) technologies (Organic Rankine Cycle and Stirling engine).

FINAL EXAM

Graded Module, Oral exam

Responsible Profs Barbara Zanuttigh, Saverio Ottaviano (UNIBO)

STATISTICS OF FINANCIAL MARKETS (UNIBO-15)				
Frequency Winter Semester	**Duration** One Semester	**Second Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 60%, Lab 20%, Direct discussion 20%		**Language** English	**Contact hours per week** 6	
CONTENT				
Trend extraction (modelling): Basic time series decomposition, Trend extraction with technical analysis (graphical approach and Moving Averages), Trend extraction with statistical model: Deterministic and stochastic trends, pairs trading, Trend extraction with supervised machine learning techniques. **Trading strategies and trading algorithms**: Basic elements of a trading strategy (probabilized scenarios through security analysis), Active management techniques using statistical inference and technical analysis, Chart patterns through trend's confidence intervals. **Measuring (and benchmarking) trading performances**: Trading strategies (TS) evaluation, Forecasting errors, Cost Functions (CFs) in financial markets, Quantitative CFs, Qualitative CFs, Subjective CF, Single TS evaluation, The comparisons of rival TS, Descriptive approach, Inferential approach				
LEARNING OUTCOMES				
At the end of the course the student knows how data of the financial markets, equity indexes construction, measurement of return and risk of portfolios, techniques for the empirical estimation of the main trends in financial market prices both through analytical approach (smoothing and forecasting mean and variance) and graphical approach (technical analysis)				
FINAL EXAM				
Graded Module, Written exam				
Responsible Prof. Andrea Guizzardi				

ECONOMICS OF FINANCIAL MARKETS AND SUSTAINABLE PERSPECTIVES (UNIBO-16)				
Frequency Winter Semester	**Duration** One Semester	**Second Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 60%, Lab 20%, Direct discussion 20%		**Language** English	**Contact hours per week** 6	

CONTENT

1. Expected utility, Risk aversion measures: brief review of basic concepts.

2.Intertemporal choice under certainty.

3. Risk premia, CAPM (Capital Asset Pricing Model), A-D Pricing

4. Arbitrage pricing Theory - APT

5. Limits of CAPM. Bayesian models.

6. Asymmetric information.

7. Investing for the Long Run: the equity premium puzzle and its remedies

8. Intertemporal portfolio allocation problem in continuous time: the classic Merton's problem.

The analysis is always developed in a discrete setting, so that the mathematical prerequisites are just basic notions of probability theory, multivariate calculus and linear algebra. We also extend the course content to continuous time: all the necessary tool will be provided in class during lectures.

LEARNING OUTCOMES

The objective of the course is to identify, describe and classify climate-related financial and non-financial risks, and the impacts of these on the economy, society and the financial services sector; explain the role of different actors in climate change, including central banks, financial supervisory authorities, national and multilateral development banks, corporate banks, and institutional investors.

FINAL EXAM

Graded Module, Take home assignment, Written exam

Responsible Prof. Massimiliano Marzo

ECONOMETRICS FOR FINANCIAL MARKETS (UNIBO-17)				
Frequency Winter Semester	**Duration** One Semester	**Second Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 60%, Lab 20%, Direct discussion 20%		**Language** English	**Contact hours per week** 6	

CONTENT

1. Introduction
2. A brief overview of models for univariate stationary time series.
3. VAR models: Representation and forecast; Estimation and inference; OLS estimation; ML estimation; Linear constrained estimation; Testing linear restrictions; Tests for Granger causality.
4. Stationary and non-stationary time series: Testing for unit-roots.
5. Spurious regression and cointegration.
6. VAR and cointegration.
7. Structural VAR models: Cholesky and other identification schemes.
8. Impulse response functions and Forecast Error Variance Decomposition.

LEARNING OUTCOMES

At the end of the course the student is able to develop the econometric analysis of the class of present value models used in financial econometrics, using stationary and/or non-stationary Vector Autoregressive systems as statistical platforms upon which all theoretical restrictions are nested and tested.

FINAL EXAM

Graded Module, Written exam

Responsible Prof. Emanuele Bacchiocchi

INTENSIVE PROGRAMME (UNIBO-18)				
Frequency Summer Semester	**Duration** Two Week	**Second Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 30%, Lab 40%, Direct discussion 10%, Seminar 20%		**Language** English	**Contact hours per week** 15	

CONTENT
The course consists of two streams of lectures focused on a range of topics related to the social and economic impact of climate change and sustainability policies. The course this year will consist of two streams of lectures: climate risk and energy finance.
LEARNING OUTCOMES
This course is addressed to specializing in frontier topics with a joint effort of academics and professionals. Theoretical lectures and practical ones will allow students to acquire knowledge and ability to use it.
FINAL EXAM
Graded Module Written exam, Team project
Responsible Prof Lorenzo Torricelli (UNIBO), Guest Lecturers, Professionals

GrEnFIn-SUMMER SCHOOL AND TRAINING (UNIBO-19)				
Frequency Summer Semester	**Duration** One Week	**Second Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 30%, Lab 40%, Direct discussion 10%, Seminar 20%		**Language** English	**Contact hours per week** 30	
CONTENT				
The topic is different every year and related to a frontier issue in the field of green finance.				
LEARNING OUTCOMES				
This course aims at specializing in frontier topics with a joint effort of academics and professionals. Theoretical lectures and practical ones will allow students to acquire knowledge and ability to use it.				
FINAL EXAM				
Graded Module Written exam, Team project				
Responsible Prof. Silvia Romagnoli (UNIBO), Guest Lecturers, Professionals				

LMU

STOCHASTIC CALCULUS AND ARBITRAGE THEORY IN CONTINUOUS TIME (LMU-01)				
Frequency Winter Semester	**Duration** One Semester	**First Semester**	**Credits** 9	**Workload** 225h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture		**Language** English	**Contact hours per week** 6	
CONTENT				
The module treats the modelling of financial markets and arbitrage pricing theory in continuous time. The first part of the lecture introduces stochastic calculus for Brownian motion, which constitutes the mathematical foundations of financial markets modelling in continuous time. Main aspects are stochastic integral for Brownian motion, Girsanov's theorem, martingale representation, stochastic differential equations, Feynman-Kac formula. Based on these mathematical tools, the second part of the module deals with the arbitrage pricing theory in continuous time for financial market models driven by Brownian motion. Main aspects here are: arbitrage and complete markets, equivalent local martingale measures, fundamental theorems of asset pricing, arbitrage free pricing and hedging of contingent claims. Important examples include the pricing and hedging of plain vanilla and exotic options in the (generalized) Black-Scholes models as well as in some popular stochastic volatility models.				
LEARNING OUTCOMES				
The aim of the module is to convey the foundations of Ito calculus for Brownian motion and arbitrage theory for financial markets in continuous time. A critical understanding of model assumptions and model purposes in the applications of financial models is developed, where in particular the Black-Scholes model as standard reference on financial markets is considered in more detail. The module serves as indispensable preparation for all further modules in financial mathematics.				
FINAL EXAM				
Graded Module, Written exam				
Responsible Prof Thilo Meyer-Brandis				

ADVANCED TOPICS IN FINANCIAL MATHEMATICS C (LMU-02)				
Frequency Winter & Summer Semester	**Duration** One Semester	**Third Semester**	**Credits** 3	**Workload** 90h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture		**Language** English	**Contact hours per week** 2	
CONTENT				
This module comprises advanced areas of financial and insurance mathematics.				
LEARNING OUTCOMES				
The aim of the module is to familiarize students with advanced questions and methodological approaches in financial and insurance mathematics. With the knowledge they have acquired, they are able to work independently in this field.				
FINAL EXAM				
Graded Module Written or Oral Exam				
Responsible Prof. Dr. Biagini				

ADVANCED TOPICS IN FINANCIAL MATHEMATICS B (LMU-03)				
Frequency Winter Semester	**Duration** One Semester	**First Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture		**Language** English	**Contact hours per week** 6	
CONTENT				
The module deals with the mathematical description and analysis of complex random phenomena, in particular with temporal and spatial dependencies. It requires in-depth knowledge of measure-theoretical probability theory. The module deals with the following topics: • Weak convergence, compactness criteria • Markov processes in discrete and continuous time: recurrence and transiency, harmonic functions, stationary processes, ergodic theorem for Markov chains				

• Stochastic processes in continuous time: Renewal processes, Poisson processes, Levy processes, Brownian motion, Donsker's invariance principle, martingales and stopping times in continuous time. These topics are the foundation for modeling different phenomena in financial mathematics and risk management.
LEARNING OUTCOMES
In this module, students acquire in-depth skills in mathematical modeling and analysis of complex random phenomena, which are crucial for modeling financial, insurance and commodity markets and risk management.
FINAL EXAM
Graded Module, Written exam
Responsible Prof. Franz Merkl

CLIMATE SYSTEM AND CLIMATE CHANGE (LMU-04)				
Frequency Winter Semester	**Duration** One Semester	**First Semester**	**Credits** 9	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture		**Language** English	**Contact hours per week** 6	
CONTENT				
Based on knowledge from introductory courses on statistical inference, advanced general concepts and methods of estimation and testing in statistical models are covered. After the basic concepts, approaches and results of classical parametric estimation and test theory, the focus is on likelihood-based and Bayesian inference concepts, which also go beyond the simple i.i.d. data situation. To this end, knowledge of both statistical theory and the algorithms associated with the methodology is taught. Further topics include bootstrap techniques and an introduction to non-parametric and semi-parametric methods as well as an outlook on current developments. Basic and in-depth knowledge of the most important concepts and methods of statistical inference will be acquired. Through the exemplary inclusion of statistical models and questions from different areas, an understanding of the universally applicable concepts, statistical theory and application relevance should be conveyed. The lecture develops the first central concepts and methods of estimation and test theory. Essential properties of the most important methods are formulated and their application is illustrated using examples, which also cover models and data relevant in the area of climate systems and climate change.				

LEARNING OUTCOMES
Students should master the theoretical foundations and the most important methods of estimation and test theory.
FINAL EXAM
Graded Module, Written exam
Responsible Prof. Christian Heumann

CLIMATE-RELATED RISK AND COMMODITY MARKET II (Elective Topics in Business Administration-Theory I) (LMU-05)				
Frequency Winter Semester	**Duration** One Semester	**First Semester**	**Credits** 6	**Workload** 180h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture and Tutorial		**Language** English	**Contact hours per week** 4	
CONTENT				
The course comprises advanced topics in business administration.				
LEARNING OUTCOMES				
The aim of the module is to expand the knowledge imparted in the basic and specialization courses to include further subject-relevant content and aspects in business administration.				
FINAL EXAM				
Graded Module Written Exam				
Responsible Faculty of Business Administration				

ECONOMETRICS (LMU-15)				
Frequency Winter Semester	**Duration** One Semester	**First Semester**	**Credits** 6	**Workload** 180h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture and Tutorial		**Language** English	**Contact hours per week** 4	
CONTENT				

This module comprises methods of econometrics, combining statistical estimation tools and economic theory. As part of the module, central concepts of econometrics are developed. The focus is on regression models for various data-generating processes and on suitable statistical estimation approaches.
LEARNING OUTCOMES
Students learn to use econometric methods to empirically test the predictions of theoretical models in economics and to create statistically sound forecasts of economic decisions made by individuals, households and companies. In addition, students should be able to follow the latest developments in the literature and assess their relevance for their own research projects.
FINAL EXAM
Graded Module Written Exam
Responsible Faculty of Economics

SEMINAR (LMU-14)				
Frequency Winter & Summer Semester	**Duration** One Semester	**First Semester**	**Credits** 3	**Workload** 90h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture		**Language** English	**Contact hours per week** 2	
CONTENT				
In this seminar, students independently work on a current mathematical topic and present it in a talk to their fellow students.				
LEARNING OUTCOMES				
In addition to the ability to independently learn a new mathematical field, students also deepen their ability to present mathematical content to others in a clear, understandable and pedagogically meaningful way.				
FINAL EXAM				
Graded Module Presentation				
Responsible Prof. Dr. Biagini				

ADVANCED TOPICS IN COMPUTER AND DATA SCIENCE B (LMU-06)				
Frequency Winter & Summer Semester	**Duration** One Semester	**Third Semester**	**Credits** 6	**Workload** 180h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture and Tutorial		**Language** English	**Contact hours per week** 4	
CONTENT				
This module covers advanced topics in the field of computer science and data science, especially but not exclusively related to automated statistical analysis and machine learning.				
LEARNING OUTCOMES				
The aim of the module is to provide students with qualifications in the fields of computer science and data science that enable them to apply and develop modern automated procedures for the statistical analysis of empirical data.				
FINAL EXAM				
Graded Module Written Exam or Oral Exam or Written Assignment				
Responsible Prof. Dr. Biagini				

FIXED INCOME MARKETS AND CREDIT DERIVATIVES (LMU-07)				
Frequency Summer Semester	**Duration** One Semester	**Second Semester**	**Credits** 9	**Workload** 225h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture		**Language** English	**Contact hours per week** 6	
CONTENT				
The module introduces into the mathematical modelling of fixed income markets and credit risk, as well as the pricing of fixed income and credit derivatives. After presenting the most important notions and products on fixed income markets, such as various types of interest rates, bonds, duration, swaps, caps, floors, and swaptions, the main approaches to modelling fixed income markets are developed. This includes short rate models, affine term structure models, Heath-Jarrow-Morton models, and LIBOR market models. Within these models, a main focus is on the derivation of analytical pricing formulas for interest rate				

derivatives using the concept of forward measures. Further, the modelling and pricing of credit risk both within structural and reduced form models is considered.
LEARNING OUTCOMES
The aim of the module is to convey comprehensive competencies in the mathematical modelling and valuation of interest rate and credit risk on fixed income markets. With the acquired knowledge, students are capable to identify appropriate quantitative tools to deal with risk on fixed income markets, as well as to critically assess the potential as well as deficits and limitations of the corresponding models.
FINAL EXAM
Graded Module, Written exam
Responsible Prof Thilo Meyer-Brandis

QUANTITATIVE RISK MANAGEMENT (LMU-08)				
Frequency Summer Semester	**Duration** One Semester	**Second Semester**	**Credits** 9	**Workload** 225h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture		**Language** English	**Contact hours per week** 6	
CONTENT				
This module deals with theoretical concepts and advanced modeling techniques of quantitative risk management in financial and insurance markets. Possible contents are: multivariate models, copulas and dependencies, risk aggregation, extreme value theory, credit risk management, operational risks, insurance risk theory, convex risk measures, financial market models with jumps (Lévy processes).				
LEARNING OUTCOMES				
The aim of this module is to introduce students to the methods and concepts of quantitative risk management. With the acquired knowledge, students are able to understand the basic structures of risk management and to apply appropriate analytical instruments in a problem-oriented manner.				
FINAL EXAM				
Graded Module, Written exam				
Responsible Prof. Katharina Oberpriller				

NUMERICAL METHODS FOR FINANCIAL MATHEMATICS (LMU-09)				
Frequency Summer Semester	**Duration** One Semester	**Second Semester**	**Credits** 9	**Workload** 75h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture		**Language** English	**Contact hours per week** 6	
CONTENT				
The lecture introduces some of the most important numerical methods and their implementation. The numerical methods are motivated by applications from mathematical finance, and their functionality is illustrated through sample implementations. Central topics include discrete approximation schemes for stochastic differential equations and Monte Carlo methods and their application to stochastic differential equations. In addition, other significant methods in financial mathematics are addressed, as they are used in processing market data, model calibration, and calculating risk parameters. The lecture also covers particular aspects of implementation, such as floating-point arithmetic or object-oriented design.				
LEARNING OUTCOMES				
Students learn some of the most relevant numerical methods and acquire the skill to create corresponding implementations. With the acquired knowledge, students can numerically solve problems in financial mathematics, such as the valuation of complex derivatives.				
FINAL EXAM				
Graded Module, Written exam				
Responsible Prof. Christian Fries				

STATISTICAL METHODS FOR FINANCIAL MATHEMATICS (LMU-13)				
Frequency Winter & Summer Semester	**Duration** One Semester	**Third Semester**	**Credits** 6	**Workload** 180h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture and Tutorial		**Language** English	**Contact hours per week** 4	
CONTENT				

This module covers selected topics of statistical analysis with reference to problems in financial and actuarial mathematics.
LEARNING OUTCOMES
In this model, students learn the methodology of statistical analysis and its application to problems in financial and actuarial mathematics.
FINAL EXAM
Graded Module Written Exam or (Written Exam and Exercises), or Oral Exam or (Oral Exam and Exercises), or Written Assignment
Responsible Prof. Dr. Augustin

INTERNSHIP/RAship (LMU-10)				
Frequency Summer Semester	**Duration** 3 Months	**Fourth Semester**	**Credits** 12	**Workload** 300h
MODULE STRUCTURE AND LANGUAGE				
Type Research		**Language** English	**Contact hours per week** TBD	
CONTENT				
In preparation for the final examination, the student performs activities in the field of sustainability, to be carried out at HEIs, research institutes, and companies.				
LEARNING OUTCOMES				
The student carries out a specific work, under the supervision of an external tutor, aimed at refining his/her learning skills and professional education.				
FINAL EXAM				
Not Graded Module Final Report				
Responsible TBD				

FINAL EXAMINATION (LMU-11)				
Frequency Summer Semester	**Duration** -	**Fourth Semester**	**Credits** 18	**Workload** 450h
MODULE STRUCTURE AND LANGUAGE				
Type Research		**Language** English	**Contact hours per week** TBD	
CONTENT				
The preparation of the final examination is devoted to activities of higher formation, in the field of industrial/scientific research in sustainability fields, to be carried out in connection with the internship/RAship experience. An academic tutor acts as supervisor as well as the external supervisor of the internship/RAship. The final thesis is written in coherence with the rule reported on the GrEnFIn-EMJM website. Discussion of the research project and the related fields.				
LEARNING OUTCOMES				
The student carries out a specific work, under the supervision of an external tutor, aimed at refining his/her learning skills and professional education.				
FINAL EXAM				
Graded Module Final Thesis				
Responsible TBD				

GrEnFIn-WINTER SCHOOL (LMU-12)				
Frequency Winter Semester	**Duration** One Week	**First/Third Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 30%, Lab 40%, Direct discussion 10%, Seminar 20%		**Language** English	**Contact hours per week** 30	
CONTENT				
The topic is different every year and related to a frontier issue in the field of green finance.				
LEARNING OUTCOMES				

This course aims at specializing in frontier topics with a joint effort of academics and professionals. Theoretical lectures and practical ones will allow students to acquire knowledge and ability to use it.
FINAL EXAM
Graded Module Written exam, Team project
Responsible Prof. TBD (LMU), Guest Lecturers, Professionals

UPD

STOCHASTIC CALCULUS (UPD-01)				
Frequency	**Duration**	**First Semester**	**Credits**	**Workload**
Winter Semester	One Semester		3	75h
MODULE STRUCTURE AND LANGUAGE				
Type		**Language**	**Contact hours per week**	
Lecture		English	6	
CONTENT				
Asset pricing, contingent claim, stochastic process, brownian motion, Itô's formula, optimal stopping time. This course is an introduction to "Derivative pricing and stochastic calculus II". It introduces the standard concepts and tools allowing to understand arbitrage theory in continuous-time. The requirements from probability theory are made as basic as possible to make the lectures accessible to students without a strong background in applied mathematics.				
LEARNING OUTCOMES				
In the end of this course, the students must be comfortable with: i) Basic concepts of contingent claims, ii) the binomial model; iii) stochastic integrals and Itôs calculus with Brownian motion; iv) Girsanov theorem v) Feynman-Kac formula vi) the Black and Scholes model, v) Merton's optimal porfolio problem.				
FINAL EXAM				
Graded Module, Written exam				
Responsible Prof René Aid				

FINANCIAL STATEMENT ANALYSIS (UPD-02)				
Frequency	**Duration**	**First Semester**	**Credits**	**Workload**
Winter Semester	One Semester		3	75h
MODULE STRUCTURE AND LANGUAGE				
Type		**Language**	**Contact hours per week**	
Lecture 60%, Lab 20%, Direct discussion 20%		English	6	
CONTENT				

The plan announced below provides a framework to follow for the course. It is indicative and flexible – some adjustments might be brought to it and would be duly announced in class. 1. Introduction: A Review of Accounting Fundamentals 2. The Financial and Analytical Income Statement 3. The Financial and Analytical Balance Sheet – From Financial Accounts to Financial Analysis 4. The Cash Cycle and Working Capital Management: From Earnings to Cash Flow 5. The Cash Flow Statement 6. The Capital Structure and Long-Term Solvency 7. Ratio Analysis and Performance Measurement 8. Discussion and Analysis of Real Case Studies 9. Conducting a Financial Analysis: Writing a Report
LEARNING OUTCOMES
This course provides a framework designed to help students learn fundamental concepts, tools and techniques to think critically when analysing a company's financial health. The objective of the course is to understand how to use, interpret and analyse the financial statements for various analytical purposes such as investment, lending and management decisions.
FINAL EXAM
Graded Module, Written exam
Responsible Prof Stéphanie Abboud (Moody's, London)

FINANCIAL MODELING with Python **(UPD-03)**				
Frequency Winter Semester	**Duration** One Semester	**First Semester**	**Credits** 3	**Workload** 75h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 60%, Lab 20%, Direct discussion 20%		**Language** English	**Contact hours per week** 6	
CONTENT				
1. Basics of Python 2. Numpy and Panda 3. Treatment of time series 4. Linear regression				

5. Financial applications: portfolio selection, factor models
LEARNING OUTCOMES
Master the basics of Python (import and data manipulation) and apply Python in finance.
FINAL EXAM
Graded Module, Project on financial data.
Responsible Prof Yannick Le Pen

PORTFOLIO MANAGEMENT (UPD-04)				
Frequency Winter Semester	**Duration** One Semester	**First Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 80%, Direct discussion 20%		**Language** English	**Contact hours per week** 6	
CONTENT				
Assuming that the classical results of portfolio theory are known, the course begins by studying problems specific to pension funds. In particular, the analysis of the interest rate risk that they bear, but also the active strategies that these funds have often initiated. Certain active strategies are examined, as are the methods used to attribute their performance. The market anomalies that active strategies seek to exploit have led to the development of factor models in which the CAPM market factor is only one of the forces determining returns. The arbitrage and equilibrium approaches of factor models are presented, along with the main empirical models. Finally, the difficulties encountered in the implementation of Markowitz-type approaches and the solutions that have been found are discussed. The Back & Litterman model, which mixes information and/or beliefs, is the best-known example.				
LEARNING OUTCOMES				
1. Understand basics of portfolio construction, modification, risk, and return. 2. Understand the interest-rate risk and hedging of pension funds. 3. Understand and implement active strategies. 4. Understand factor models. 5. Understand risk models and the Bayesian logic of modern models				
FINAL EXAM				
Graded Module, Mid-term exam (50%), Final exam (50%).				
Responsible Prof Philippe Bernard				

MICROECONOMICS and ENVIRONMENT (UPD-05)				
Frequency Winter Semester	**Duration** One Semester	**First Semester**	**Credits** 3	**Workload** 75h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 60%, Lab 20%, Direct discussion 20%		**Language** English	**Contact hours per week** 6	

CONTENT

This course introduces students to how microeconomic analysis can be used to understand current environmental issues. The general objective of this course is to present the main notions of microeconomics, applied to environmental issues. Lectures include applications (applied theory and empirics) to environmental degradation and climate change, as well as a survey of public policy issues regarding the management of natural resources and the protection of environmental quality.

The course covers both conceptual and methodological topics and recent and current applications of microeconomics applied to environmental issues. The course is divided into three parts. First (part 1), we will introduce students to the main concepts and current issues of microeconomics and environmental economics. We then explore those current issues, focusing on specific applications. In part 2, we consider the microeconomic tools for environmental regulation and policy. In part 3, we pay particular attention to Global Climate Change. It specifically includes applications where we evaluate actual climate change policy instruments such as the EU Emissions Trading Scheme or the Carbon tax.

LEARNING OUTCOMES

The main outcome of the course is to train students to express an informed view regarding the potential of microeconomics tools to help societies achieve environmental protection goals. Other learning outcomes are the following:

- Being able to manipulate the standard microeconomic tools, and their mathematical formalization, to assess the impact of environmental policies, such as command-and-control and market-based instruments. Students will learn how to build applied theoretical models, solve these models, and interpret their results.
- Examine issues in the contemporary environmental discourse from an economist's point of view.
- Know to what extent economics shape public policies to protect the environment.
- Being able to compare and confront the effects of the different policies instruments from a theoretical perspective to the analysis of impacts of contemporaneous public

policies. This will be done by reading economic research articles and reports during each class.
FINAL EXAM
Graded Module, Written exam 50% and homework 50%
Responsible Prof Loic Henry

MACROECONOMICS (UPD-06)				
Frequency Winter Semester	**Duration** One Semester	**First Semester**	**Credits** 3	**Workload** 75h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 60%, Direct discussion 40%		**Language** English	**Contact hours per week** 6	
CONTENT				
Economic growth models: Solow model, Ramsey-Cass-Koopmans model, overlapping generations growth model, endogenous growth models, growth and environment models.				
LEARNING OUTCOMES				
• Identify the determinants of growth. • Apply the tools for analyzing growth phenomena as well as theories. • Solve optimal control problems. • Solve differential equations.				
FINAL EXAM				
Graded Module, Mid-term written exam (50%), Final written exam (50%).				
Responsible Prof Audrey Desbonnet				

TIME SERIES ECONOMETRICS (UPD-07)				
Frequency Winter Semester	**Duration** One Semester	**First Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 50%, Lab 40%, Direct discussion 10%		**Language** English	**Contact hours per week** 6	

CONTENT
This course provides an overview of time series methods in econometrics. Topics covered include stationary and non-stationary process, univariate modeling and forecasting with ARMA models, and multivariate modeling with vector autoregression and error correction models. The empirical applications in the course are drawn mainly from macroeconomics and finance and are implemented using R software
LEARNING OUTCOMES
• Understanding the basic concept of time series econometrics • Acquiring the ability to model and forecast stationary and nonstationary processes • Using R for modeling and forecasting time series
FINAL EXAM
Graded Module, R project (40%), Written final exam (60%).
Responsible Prof Yannick Le Pen

DERIVATIVE INSTRUMENTS (UPD-08)				
Frequency Winter Semester	**Duration** One Semester	**First Semester**	**Credits** 3	**Workload** 75h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture		**Language** English	**Contact hours per week** 6	
CONTENT				
Introduction to risk management and derivatives instruments, Mechanics of Futures Markets, Determination of Forward and Futures Prices, Hedging Strategies Using Futures Interest Rates, Interest Rate Futures, Swaps, Mechanics of Options Markets, Properties of Stock Options, Trading Strategies Involving Options.				
LEARNING OUTCOMES				
The purpose of this course is to present the functioning of derivative products, namely forwards, futures, swaps and options, both in a risk management and speculation perspective.				
FINAL EXAM				
Graded Module, Written final exam.				
Responsible Prof Jérôme Mathis				

CORPORATE LAW AND BUSINESS ETHICS (UPD-09)				
Frequency	**Duration**	**Third Semester**	**Credits**	**Workload**
Winter Semester	One Semester		3	75h

MODULE STRUCTURE AND LANGUAGE		
Type	**Language**	**Contact hours per week**
Lecture 60%, Direct discussion 40%	English	6

CONTENT

Key Texts: Sustainable Finance, Taxonomy, NFRD Directive (later CSRD) "Green Communication", Disclosure Regulation (SFDR) - Financial Sector
Greenwashing - Act 1: Unfair Commercial Practices, Definition of Unfair Commercial Practices, Nature of Unfair Practices, Professional Diligence, What Sanctions?
Misleading Commercial Practices: Generalities, Who?, Sanctions
Greenwashing- Act 2: Developments, Context - Judicial Pressure, Attention to Communication, Evolution of Regulation since August 30, 2021, Environmental Shareholder Activism
Purpose-driven company: Commitments that... Commit, PACTE Law, Purpose, and Benefit Corporation Status
Duty of Vigilance - Law and Directive: Vigilance Law, Obligations of the Vigilance Law, Content of the Plan, Publicity of the Plan, Sanctions, Vigilance Directive, Activities Chain and Responsibility, Main Measures
Corruption Prevention: Small Lexicon of Corruption, Why the Sapin II Law, General Presentation of the System, Organizational Impacts: Under the Supervision of Executives, Creation of the French Anti-Corruption Agency, Judicial Public Interest Agreement, Whistleblowers, Whistleblowers - New European Framework
Representation of Interests: HATPV, Generalities, Criteria for Representation of Interests.

LEARNING OUTCOMES

Presentation and analysis of preventive measures and transparency obligations: combating money laundering and terrorism financing, anti-corruption efforts, data protection and GDPR, duty and vigilance plan, and non-financial reporting.

FINAL EXAM

Graded Module, Written exam and Final individual paper.

Responsible Prof. Dominique Didieu

LEADERSHIP IN FINANCE (UPD-10)				
Frequency Winter Semester	**Duration** One Semester	**Third Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture		**Language** English	**Contact hours per week** **3**	

CONTENT

As participant of this research driven lecture, you will receive an overview about leadership theories, current new leadership theory developments and principal strategic and operative leadership topics that arise in companies and the economy. We will interactively discuss in the class topics such as leadership in strategic management and globalized economies, approaches of leadership effectiveness, leadership that transforms the company from "good to great", leadership and generation Y or leadership in competitive decision making and negotiations, team leadership and leading with emotional, social and cultural intelligence.

Literature

Textbooks, cases and research articles (more information will be provided at the beginning of the course). Selected recommended textbooks. Northouse, Leadership - Theory and Practice; Bass Handbook of Leadership; Kotter, Leading Change; Kotter, Force for Change: How Leadership differs from Management.

LEARNING OUTCOMES

Learning goals for Leadership in the Financial Industry (LFIN)

• Gaining knowledge and understanding on the fundamental leadership theories and models. • Gain in-depth knowledge in decision-making skills and learn how to lead cross-functional initiatives in today's shifting global markets.

• Build strategic leadership skills for effective strategy development and implementation.

• Cultivating a sense of self-awareness by identifying a leadership vision, mission, style and values.

• Gaining leadership training with case studies and education for a career of professional excellence.

• Gaining knowledge and ability to inspire and develop others.

• Exhibiting knowledge and awareness of diversity around identities, cultures, and society.

• Developing communication skills and the ability to interrelate with others.

•Enhancing awareness and commitment towards effective citizenship and social responsibility.

FINAL EXAM
Graded Module, Written exam and Project
Responsible Prof. Mathias Reinoso

GREEN FINANCE: MARKET FINANCE AND PROJECT FINANCING (UPD-11)				
Frequency	**Duration**	**Third Semester**	**Credits**	**Workload**
Winter Semester	One Semester		6	150h
MODULE STRUCTURE AND LANGUAGE				
Type		**Language**	**Contact hours per week**	
Lecture		English	6	
CONTENT				

Part A: Project Finance: in the initial session, we delve into Project Finance, comparing it with corporate finance, conducting risk analysis, exploring its impact on contractual frameworks, and providing an overview of lenders, debt raising processes, and syndication. The subsequent session continues with an introduction to financing documentation, the investors' perspective, and a case study on offshore wind financing & refinancing. The third session focuses on cashflow modeling, introducing financial models, and conducting a modeling exercise using Excel. The final session features a panel discussion with speakers from developers, banks, and advisors sharing diverse perspectives on Project Finance.

Part B: Market Finance: The opening chapter aims to review financial market fundamentals and assess the environmental impact of human activities, particularly focusing on climate change. The second chapter delves into recent studies on environmental risks, socially responsible investment motivations, and challenges in environmental finance. The third chapter explores the environmental and sustainable practices of institutional investors, including methods like exclusion, ESG screening, corporate engagement, and impact investing. The fourth chapter shifts the focus to financing green assets, covering various securities such as green bonds, project bonds, sustainable infrastructure, real estate, green funds, and labels. The fifth chapter presents metrics for measuring environmental impact, including carbon footprint, carbon intensity, green/brown share, stranded assets, avoided emissions, 2-degree alignment, and Net Environmental Contribution (NEC). The final chapter examines the concerns of central banks regarding environmental impact, their integration of systemic risk management into their mandate, and the associated limitations.

LEARNING OUTCOMES
This course is designed to provide students with the tools to understand and support the greening of the financial system by articulating concrete examples, academic papers, and latest regulations.
FINAL EXAM
Graded Module, Written exam
Responsible Prof. Emille Marbot

MACROECONOMICS OF MARKET PARTICIPANTS (UPD-14)				
Frequency Winter Semester	**Duration** One week	**Third Semester**	**Credits** 3	**Workload** 75h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture		**Language** English	**Contact hours per week** 3	
CONTENT				
I. How market participants follow and respond to the business cycle: an analytical framework II. The interest rate markets III. The stock markets IV. The exchange rate markets				
LEARNING OUTCOMES				
The aim of the course is to provide students an overview of the interaction between the macro-economic environment and financial markets developments.				
FINAL EXAM				
Graded Module Written exam and project				
Responsible Prof. Florence Pisani				

PYTHON-MACHINE LEARNING (UPD-15)				
Frequency Winter Semester	**Duration** One week	**Third Semester**	**Credits** 3	**Workload** 75h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 50%, Lab 50%		**Language** English	**Contact hours per week** 3	

CONTENT

Part 1: Python

I – Python basis reminder
II – Numpy: vector/matrix computation
III – Matplotlib: plotting results

Part 2: Machine Learning

1. *Fundamental ML concepts*
a. What is ML / theoretical background
b. In practice what do we care about when we train a ML model?
c. Example: Linear Regression on Boston Houses dataset
d. Going further: validation scheme, regularisation
e. Logistic regression: from regression to classification

2. *More powerful models*
a. Limits of linear models (xor / blobs)
b. Tree based models (CART, Random Forest, Gradient boosting)
c. Example: Allstate insurance dataset (from Kaggle compétition)

3. *Dealing with non-structured data*
a. Images: MNISTdataset
b. Text: IMDB review dataset (TF-IDF,…)

4. *Intro to deep learning / Datascience workflow in industry*

LEARNING OUTCOMES

Go to python in depth in studying some calculations libraries.

FINAL EXAM

Graded Module
Python project.

Responsible
Prof. Adrien Husson

SAS/R/SQL DATA ANALYSIS, DATA MODELING (UPD-16)				
Frequency Winter Semester	**Duration** One week	**Third Semester**	**Credits** 3	**Workload** 75h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 60%, Lab 40%		**Language** English	**Contact hours per week** 3	
CONTENT				
This course is an introduction to SAS, a software tool for statistical analysis, the Structured Query Language (SQL) and R, a programming language and software environment for statistical computing and graphics. You will also be introduced to algorithmics, in order to understand the underlying mechanisms of different statistical analysis techniques. .				
LEARNING OUTCOMES				
In this course, you will learn how to create and modify database structures, and how to retrieve, manipulate and summarize data, as well as how to conduct basic statistical analyses and create visualizations of your data using those tools. By the end of this course, you will have foundation knowledge in SAS, R and SQL and algorithmics. You will be able to use it to analyze and interpret data to your own analysis projects, in a variety of fields, including business, finance, marketing, and the social sciences				
FINAL EXAM				
Graded Module Written exam and project				
Responsible Jérôme Lepagnol				

Co-funded by the European Union

Greening Energy Market and Finance
Erasmus Mundus Joint Master
GrEnFIn-EMJM

EMPIRICAL MODELING OF ELECTRICITY AND GAS MARKETS (UPD-17)				
Frequency Winter Semester	**Duration** One week	**Third Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 60%, Seminar 40%		**Language** English	**Contact hours per week** 3	
CONTENT				
The course focuses on how the main characteristics of day-ahead electricity markets and gas markets are modeled, in terms of empirical industrial organization and econometrics. Concrete cases and examples will be presented. Each lecture closely follows the most recent empirical literature on the topic presented. Bibliography (optional) • Bushnell J., Mansur E. , Saravia C. “Vertical Arrangements, Market Structure, and Competition: An Analysis of Restructured U.S. Electricity Markets”, American Economic Review, Volume 98, Issue 1, March 2008, pages 237-266. • Chaton C. Creti A and B. Villeneuve (2009) “Storage and Security of Supply in the Medium Run", Resource and Energy Economics, Vol 31, pp 24-38 • Creti A.(2004) "Long-term Contracts and Take-or-pay Clauses in Natural Gas Markets", (with B. Villeveuve), Energy Studies Review, Vol 13, pp 75-94 • Cremer H., Laffont J-J. (2002), Competition in gas markets, European Economic Review 46, 928– 935 • Mansur E. “Measuring Welfare in Restructured Electricity Markets ”Review of Economics and Statistics, Volume 90, Issue 2, May 2008, pages 369-386 • Newbery, D. et al. “A Review of the Monitoring of Market Power” Working Papers 0502, Massachusetts Institute of Technology, Center for Energy and Environmental Policy Research				
LEARNING OUTCOMES				
Learning how to model the main characteristics of electricity and gas markets. Students will learn to apply the most recent theories to analyze the performance of these markets, as well as to understand empirical and simulation analysis that are frequently used by both regulators and firms to assess the effects of changes in market design or market structure.				
FINAL EXAM				
Graded Module Written Exam				
Responsible Prof. Anna Créti				

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

Dauphine | PSL UNIVERSITÉ PARIS

ADVANCED METHODS FOR RISK MANAGEMENT (UPD-18)				
Frequency Winter Semester	**Duration** One week	**Third Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture		**Language** English	**Contact hours per week** 3	

CONTENT

Session	Topic
1	Market risk and the definitions of "price", "risk factor" and "sensitivity"
2	Risk factors and risk mapping for linear, non linear and structured products
3	Spread risk single name (CSR risk): bond and CDS spread
4	Credit risk models: structural and intensity based models
5	Correlation risk and copula functions
6	Modern Portfolio Theory and Risk Model Review: from CAPM to advanced Statistical Multi Factor risk model
7	Top Level and Position based risk indicators for Risk Analysis and Risk Management
8	Advanced Risk measures: Tail Risk and Asymmetrical Risk - VaR and ES with Monte Carlo Approach
9	Risk & Performance Attribution: Position Based vs Risk Based – Factor Based performance Attribution
10	Portfolio Construction and Optimization
11	**Final Exam**

Bibliography

1. F. Chauvet, Allocation d'Actifs – Théorie et Pratiques, ch. 5: La Gestion du risque, 2024
2. S. Ross, Return, Risk and Arbitrage, 1976

LEARNING OUTCOMES
At the end of the course the student is familiar with the main principles and tools of market risk analysis and the hedging techniques. She/He can design a process of market risk measurement and reporting, and make market risk management decisions. Risk management will be examined from both a sell-side and buy-side perspective.
FINAL EXAM
Graded Module Written exam
Responsible Karim Jacquelin and Jonathan Levy

ECONOMY OF CLIMATE CHANGE (UPD-19)				
Frequency Winter Semester	**Duration** One week	**Third Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture		**Language** English	**Contact hours per week** 30	
CONTENT				

Climate change is primarily linked to an energy model historically based on fossil fuels (coal, oil, and natural gas) since the first industrial revolution. Limiting the main effects of climate change (extreme weather events, air pollution, sea-level rise, etc.) and their economic costs involve deploying low-carbon energy means (wind, solar, etc.), improving energy efficiency, and, more broadly, transforming the organization of our societies. In this context, the course examines:

- Economic theory, empirical perspectives, and the political economy of the supply and demand for energy, both for fossil fuels and renewable energy sources.
- Public policies affecting energy markets, including taxation, price regulation and deregulation, energy efficiency, and emission control.
- Special attention will be given to economic policies such as carbon taxes and tradable emission permits, as well as issues related to replacing fossil fuels with new energy technologies.

LEARNING OUTCOMES
Skills in Climate Change Economics.

FINAL EXAM
Graded Module Written exam 30%, Team project 70%
Responsible Prof. Patrice Geoffron

ENERGY AND ENVIRONMENTAL ECONOMICS (UPD-20)				
Frequency Winter Semester	**Duration** One week	**Third Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture		**Language** English	**Contact hours per week** 30	
CONTENT				
Transmission of fundamental knowledge in energy and environmental economics. The class will offer students an overview of key concepts in both environmental and energy economics, allowing them to apply these concepts to basic policy analysis. Topics covered include externalities, fixed costs, information, optimal internalization of externalities, dimensions of social cost, measurement of externalities, special topics like distribution and energy efficiency, electricity markets, the full costs of low carbon electricity systems, and the interaction of carbon and electricity markets.				
LEARNING OUTCOMES				
The class will provide students with an overview of key concepts in both environmental economics and energy economics with a special focus on the performance of European electricity markets. The class will develop those notions in a framework alternating between private and social utility maximisation.				
FINAL EXAM				
Graded Module Written exam				
Responsible Prof. Jan-Horst Keppler				

BEHAVIORAL FINANCE (UPD-21)				
Frequency Winter Semester	**Duration** One week	**Third Semester**	**Credits** 3	**Workload** 75h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 60%, Direct discussion 40%		**Language** English	**Contact hours per week** 30	
CONTENT				
Behavioral finance courses involve a mix of theory, empirical studies, and practical applications to help students understand how psychological factors impact financial decision-making.				
LEARNING OUTCOMES				
These learning outcomes collectively equip students with the knowledge and skills to understand, analyze, and navigate financial decision-making through the lens of behavioral finance.				
FINAL EXAM				
Graded Module Written exam and teamwork				
Responsible Prof. Jean-Philippe Lefort				

INVESTING ON FINANCIAL MARKETS (UPD-22)				
Frequency Winter Semester	**Duration** One week	**Third Semester**	**Credits** 3	**Workload** 75h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 60%, Direct discussion 40%		**Language** English	**Contact hours per week** 30	
CONTENT				
The course aims at grasping key financial asset management principles and concepts, their goals, major means, common tools & constraints, in a search of a "reasonably optimal" portfolio. I-A review of investment processes, techniques and models over time II-Investment Process: investment philosophy, investment universe, asset selection, portfolio construction, risk monitoring, reporting				

III-Diversification, factors & risk premia IV-Risks & return assessment (VaR, CVaR, EVT, major ratios) V-Directional & non-directional strategies for relative or absolute expected returns VI-SRI, ESG and other non-financial inputs VII- Case studies (investment themes & asset managers)
LEARNING OUTCOMES
Understanding asset management's purpose and optimization. Understanding uncertainty reduction techniques to improve investment decisions over time. Portfolio construction & risk-return analyses.
FINAL EXAM
Graded Module Written exam and teamwork
Responsible Prof. Denis Beaudoin

CORPORATE STRATEGY (UPD-23)				
Frequency Winter Semester	**Duration** One week	**Third Semester**	**Credits** 3	**Workload** 75h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 60%, Direct discussion 40%		**Language** English	**Contact hours per week** 30	
CONTENT				
Strategy of External Growth, Acquisition Integration Challenge, M&A Deal Life Cycle, Investment, Private Equity, Ventures Capital, Successful Contractual Clauses, Strategic Alliances and Partnership, Corporate Divestiture, Process of Initial Public Offering (IPO).				
LEARNING OUTCOMES				
The course aims to understand the various strategies of external growth through Mergers and Acquisitions, Investments, Private Equity, Venture Funds, Strategic Alliances and Partnerships. Key trigger points for Successful Acquisition, Integration, IPO, Due Dilligence, Exit. Divestitures, etc.				
FINAL EXAM				
Graded Module Written exam and teamwork				
Responsible Prof Christelle Gannage				

GrEnFIn-SUMMER SCHOOL (UPD-24)				
Frequency Summer Semester	**Duration** One week	**Second Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Lecture 30%, Lab 40%, Direct discussion 10%, Seminar 20%		**Language** English	**Contact hours per week** 30	
CONTENT				
The topic is different every year and related to a frontier issue in the field of green finance.				
LEARNING OUTCOMES				
This course aims at specializing in frontier topics with a joint effort of academics and professionals. Theoretical lectures and practical ones will allow students to acquire knowledge and ability to use it.				
FINAL EXAM				
Graded Module Written exam, Team project				
Responsible Prof. TBD (UPD), Guest Lecturers, Professionals				

INTERNSHIP/RAship (UPD-12)				
Frequency Summer Semester	**Duration** 2 Months	**Fourth Semester**	**Credits** 6	**Workload** 150h
MODULE STRUCTURE AND LANGUAGE				
Type Research		**Language** English	**Contact hours per week** TBD	
CONTENT				
In preparation for the final examination, the student performs activities in the field of sustainability, to be carried out at HEIs, research institutes, and companies.				
LEARNING OUTCOMES				
The student carries out a specific work, under the supervision of an external tutor, aimed at refining his/her learning skills and professional education.				
FINAL EXAM				

Not Graded Module Final Report
Responsible Prof. TBD (UPD)

FINAL EXAMINATION (UPD-13)				
Frequency Summer Semester	**Duration** -	**Fourth Semester**	**Credits** 24	**Workload** 600h
MODULE STRUCTURE AND LANGUAGE				
Type Research		**Language** English	**Contact hours per week** TBD	
CONTENT				
The preparation of the final examination is devoted to activities of higher formation, in the field of industrial/scientific research in sustainability fields, to be carried out in connection with the internship/RAship experience. An academic tutor acts as supervisor as well as the external supervisor of the internship/RAship. The final thesis is written in coherence with the rule reported on the GrEnFIn-EMJM website. Discussion of the research project and the related fields.				
LEARNING OUTCOMES				
The student carries out a specific work, under the supervision of an external tutor, aimed at refining his/her learning skills and professional education.				
FINAL EXAM				
Graded Module Final Thesis				
Responsible TBD				