UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Planetary Boundaries As Basis for Sustainability Concepts

2526-1-F7603Q005

Aims

The main aim of the course is to raise awareness of the fact that the Earth System is made up of a series of interrelated systems and that human activity is altering the balances that have made the development of human civilisation possible in the first place. In this context, the objective of sustainable use of resources is maintaining and improving living standards, limiting environmental pressure and consequently minimizing ecological and human health related impacts. Socio-economic systems rely upon ecosystems, sustainability aims at enabling human development without jeopardising the Earth's ecosystems. The most important environmental challenges that humankind is facing, such as climate change and extinction of species, are all interlinked. The underpinning drivers of such impacts should be addressed in a systematic manner.
This necessitates the maintenance of the planet's ecological life-support system, which encompasses natural capital and ecosystem services, for an indefinite period. Consequently, from an economical, political and social point of view, reaching sustainable standards requires a new evaluation of responsibilities and strategies of the production and consumption chain starting from raw materials and feedstock.
The question of sustainability is contingent upon a range of factors, including the environmental impacts associated with the material used, the scale at which it is deployed, the existence of alternative resources, and the efficiency with which resources are utilised.
Fossil, mineral and metals and biomass resources are the key input to production and consumption systems. Their availability, supply risk, circularity and substitutability are some of the key elements needed to understand their role in the society. Moreover, extraction and use of resources is the main driver of the abovementioned environmental impacts.
In this regard, the use of biomass derived from natural resources and waste materials currently constitutes an important proportion of renewable energy output, while also representing a growing share of material inputs to the bioeconomy. Moreover, there is a clear competition in the demand of biomass for different uses and it is utmost to understand which are the key sustainability challenges associated with this (e.g. feed, food, energy and biomaterials).
This course examines this aspect together with a multitude of interrelated factors regarding biomass use, including direct and indirect land use impacts. It also considers waste management and residue utilisation, and the broader environmental implications of such production and use.

Knowledge and understanding
At the end of the course the student will have a fundamental understanding of:
• the theoretical development of the concept of limits in ecology, carrying capacity, planetary boundaries and links to footprinting;
• the main ecological issues and challenges in the face of global changes;
• concepts of sustainability;
• definition of resources (abiotic and biotic resources), primary and secondary;
• classification of biomass based on origin, characteristics and sustainability;
• basics of plant biology and ecology;
• biomass valorisation in the productive and energetic supply chain;
• main parameters to be evaluated to define a low environmental impact process and product/service;
• fundamentals of the bioeconomy and its circularity;
• challenges and opportunities in bioeconomy;
• international and European legislative frameworks connected to the fields of environmental sustainability.

Applying knowledge and understanding
At the end of the course the student will be able to:
• discuss the concept of sustainability learned in the course that forms the basis of sustainable development according to the UN 2030 agenda;
• understand differences in renewable and not renewable resources;
• understand the concept of circularity of resources;
• apply fundamentals of circular bioeconomy;
• refer to a set of the main ecological indicators;
• know the International and European legislative frameworks connected to the fields of environmental sustainability.

Making judgements
At the end of the course the student will be able to:
• assess the interlinkages between resources, production and consumption systems, environmental pressure and ecological impacts, addressing them in light of Earth ecological limits.

Communication skills
At the end of the course the student should be able to:
• analyze case studies of sustainable use of resources in a clear and concise way;
• explain orally with a suitable language the objectives, the procedures and the results of the elaborations carried out.

Learning skills
At the end of the course the student should be able to:
• understand topics covered in the scientific literature concerning the sustainability issue.

Contents

• Basics of Ecology.
• Geological time and the Anthropocene.
• Nine environmental boundaries.
• Ecosystem services, Renewable resources in the global change era.
• The importance of biomass as renewable resource.
• Main EU and international policies regarding biomass use as renewable resource.
• Basics of plant biology and ecology.
• Classification of biomass based on origin, characteristics and sustainability.
• Pathways and processes of biomass valorisation in the productive and energetic supply chain.

• Biomass in circular economy.
• Challenges and opportunities in the cascading use of biomass as feedstock.
• Real-world examples of sustainable biomass management in the productive and energetic supply chain.
• Definition of abiotic resources and raw materials.
• Understand the concept of non-renewable resources and their environmental impacts.
• Responsible and sustainable use of non-renewable resources such as metals, aspects of recycling within a circular economy.
• Learn about resource efficiency and circularity and its importance in sustainable development.
• Understand the concept of planetary boundaries in relation to abiotic and non-renewable sustainable resource management.
• Learn about life cycle assessment (LCA), environmental and ecological footprint and link with planetary boundaries, addressing relative and absolute sustainability concepts.
• Analyse case studies and real-world examples of sustainable resource management.The main EU and international policies linking resources, supply chains assessment., planetary boundaries and sustainability.

Detailed program

• Geological time.
• The Anthropocene debates.
• Concept of systems and complexity of ecological systems.
• Limits and tipping point.
• Environmental surprises.
• Planetary boundaries and doughnuts economy.
• Ecosystem services.
• Overview of renewable resources.
• Evolution of biomass as a feedstock in the bioeconomy and its direct or indirect origin from plants.
• Principles of plant biology and ecology related to the use of plants as biomass in the productive and energetic supply chain.
• Classification of biomass into generations.
• Chemical components of interest for the production of high value-added compounds and bioenergy from biomass.
• Processes and technologies for the production of bioenergy from biomass: thermochemical, biological and physical conversion.
• Essential biomass parameters to be considered when choosing the appropriate conversion technology.
• Cascading principles for the use of biomass.
• Interdisciplinary case studies of the use of biomass in the bioeconomy.
• Definition of abiotic resources, availability, supply risk, demand in main sectors and technologies.
• Distribution of elements across various environments using (anthro)biogeochemical cycles.
• Sustainable mining activities.
• Global trends and challenges in non-renewable resource management.
• Definition and importance of resource efficiency.
• Strategies for improving resource efficiency and circularity (reduce, reuse, recycle, etc.).
• Key concept of circular economy, including recycling, downcycling and upcycling.
• Description of the challenges associated with the recycling and reuse of various materials, including precious metals, concept of urban mining.
• Abiotic resources and associated environmental impacts due to extraction, use, and waste management.
• The integration of sustainable processes within the circular economy.
• The novel entities.
• Introduction to life cycle assessment (LCA) and footprints approaches to supply chain assessment.
• Applications of LCA in sustainable resource management.
• Relevance of planetary boundaries to sustainable resource management.
• Overview of EU and international policies for sustainable resource. management (e.g. Circular Economy

Package, critical Raw Materials Act) and link with planetary boundaries (e.g. 8th Environmental Action Program “Living well within the limits of our Planet”).
• Overview of EU and international policies for supply chain assessment
• International cooperation and global governance of sustainable resource management.
• Case studies on key sectors and technologies.

Prerequisites

• Basic understanding of environmental science.
• Basic understanding of sustainability concepts.

Teaching form

12 CFUs of theoretical lessons (96 hours, with 72 hours/9 CFU of lessons in person and 24 hours/ 3 CFU of lessons online):
• 60 hours lectures, in person, Delivered Didactics;
• 36 hours of analysis and discussion about different case studies, in person, reading and discussing scientific articles in aula, also in common with colleagues of other modules, Mixed Didactics, / Seminar.

Attendance to lectures and interactive exercises is highly recommended.

Textbook and teaching resource

• United Nations Environment Programme (2024): Global Resources Outlook 2024: Bend the Trend – Pathways to a liveable planet as resource use spikes. International Resource Panel. Nairobi. https://wedocs.unep.org/20.500.11822/44901
• World Economic forum (2025) 2025 Global risk report https://www.weforum.org/publications/global-risks-report-2025/
• Juan F. Velasco-Munoz, Chaudhery Mustansar Hussain (2021) Sustainable Resource Management: Modern Approaches and Contexts. Elsevier ISBN: 9780128243428
• Hauschild, M. Z., Rosenbaum, R. K., & Olsen, S. I. (2018). Life cycle assessment Springer International Publishing, Cham. https://doi. org/10.1007/978-3-319-56475-3.
• Slides.
• Notes shown during lectures and additional material on selected topics, *i.e.*, scientific articles, made available on the e-learning website of the course.

Semester

I semester (October - January)

Assessment method

The final exam consists of a single written exam at the end of the course, which comprises the discussion of various topics covered in the course within the three modules, with an emphasis also on the connections between concepts and processes, such as to arrive at a critical evaluation of work from the point of view of planetary boundaries and responsible use of renewable and non–renewable resources.

The final score will be between 18/30 and 30/30 *cum laude*, based on the overall assessment considering the following criteria:
(1) knowledge and understanding;
(2) ability to connect different concepts;
(3) autonomy of analysis and judgment;
(4) ability to correctly use scientific language.

Office hours

Students are asked to refer to the indications provided in the syllabi of the modules.

Sustainable Development Goals

QUALITY EDUCATION | CLEAN WATER AND SANITATION | AFFORDABLE AND CLEAN ENERGY | INDUSTRY, INNOVATION AND INFRASTRUCTURE | SUSTAINABLE CITIES AND COMMUNITIES | RESPONSIBLE CONSUMPTION AND PRODUCTION | CLIMATE ACTION