UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Planetary Boundaries As Basis for Sustainability Concepts

2627-1-F7603Q005

Aims

General aims
Socio-economic systems rely upon ecosystems, sustainability aims at enabling human development without jeopardizing 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 economic, 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.

Accordingly, the course aims to provide an integrated understanding of sustainability based on planetary boundaries, ecological limits and the responsible use of biotic and abiotic resources.
Starting from the Earth System as a set of interconnected ecological, geological, atmospheric, hydrological and socio-economic subsystems, the course addresses how production and consumption systems alter environmental balances and generate pressures on ecosystems, resources and human societies.
The course combines three complementary perspectives: ecological foundations for interpreting global change and planetary boundaries; the role of plant biomass and organic residues as renewable feedstock for bioenergy and bioproducts; and the management of abiotic and non-renewable resources, including supply risk, criticality, circularity and environmental impacts.
Students will be introduced to concepts and tools such as ecosystem services, circular economy, cascading use, resource efficiency, life cycle assessment, footprints and policy frameworks, with the aim of evaluating sustainability beyond single-sector perspectives.
Through interdisciplinary case studies, students will learn to connect ecological processes, resource availability, technological options, environmental externalities and socio-economic constraints, developing the ability to critically assess strategies for the responsible use of renewable and non-renewable resources within planetary boundaries.

Knowledge and understanding
At the end of the course, students will have developed a fundamental understanding of:
• ecological limits, carrying capacity, planetary boundaries, the Anthropocene and their links with sustainability and footprinting approaches;
• the structure and functioning of the Earth System and the interconnections among ecological, geological, atmospheric, hydrological and socio-economic subsystems;
• ecosystem services, natural capital and the role of ecological processes in supporting human development and production systems;
• the classification of resources, including biotic and abiotic resources, renewable and non-renewable resources, primary resources and secondary resources;
• the biological and ecological basis of plant biomass production, biomass classification and its valorisation in energy and productive supply chains;
• the principles of bioeconomy, circular economy, cascading use, resource efficiency and circularity, including their limits and trade-offs;
• the availability, supply risk, environmental impacts and criticality of abiotic and non-renewable resources;
• life cycle assessment, footprinting approaches and their use in connecting supply chains, environmental impacts and planetary boundaries;
• the main international policy frameworks related to environmental sustainability, renewable and non-renewable resources, circular economy and supply-chain assessment.

Applying knowledge and understanding
At the end of the course, students will be able to:
• apply the concept of sustainability and planetary boundaries to the analysis of production and consumption systems;
• distinguish renewable and non-renewable resources and discuss their different roles, constraints and impacts in sustainable development;
• interpret ecological indicators, ecosystem-service concepts, footprinting approaches and LCA-based information in the assessment of environmental pressure;
• analyse biomass use as renewable feedstock, identifying suitable valorisation pathways according to biomass origin, characteristics, sustainability and circular-economy principles;
• analyse the use of abiotic and non-renewable resources, considering availability, criticality, resource efficiency, circularity and environmental externalities;
• connect biological, ecological, chemical-physical, technological, economic and regulatory information when evaluating resource-management strategies;
• discuss interdisciplinary case studies by integrating evidence from the three modules and relating them to the UN 2030 Agenda and European and international sustainability frameworks.

Making judgements
At the end of the course, students will be able to:
• critically assess the interlinkages among resources, production and consumption systems, environmental pressures and ecological impacts in light of Earth-system limits;
• evaluate trade-offs between renewable and non-renewable resource use, including energy demand, material demand, land use, biodiversity, pollution, supply risk and socio-economic externalities;
• compare alternative circularity, recycling, cascading-use and biomass-valorisation strategies, identifying their strengths, limitations and possible rebound effects;
• critically interpret scientific literature, LCA results, footprint-based assessments and technical-regulatory documents;
• integrate ecological, technological, chemical, legal and economic perspectives to address complex sustainability problems;
• evaluate policies, plans and programmes related to sustainable resource management, circular economy and climate and environmental objectives;
• independently develop and critically discuss the final case study, supporting judgements with scientific evidence and appropriate methodological choices.

Communication skills

At the end of the course, students will be able to:
• communicate, using appropriate scientific terminology, the main ecological, technological and socio-economic issues related to planetary boundaries and sustainable resource use;
• present and discuss interdisciplinary case studies concerning renewable and non-renewable resources in a clear, structured and critical way;
• explain the objectives, methods, results and limitations of sustainability assessments, including LCA, footprinting and resource-efficiency analyses;
• interact with third parts during discussions, supporting arguments with scientific, technical and regulatory evidence.

Learning skills
At the end of the course, students will be able to:
• apply the acquired knowledge to identify best practices for sustainable resource use and to support future policies and management strategies;
• apply the acquired knowledge to new contexts, different from those specifically addressed in the course, independently integrating it with other sources of information;
• consult international scientific literature, databases and technical reports from research centres, local authorities, governments and international organizations;
• work both in groups and independently, using the scientific method as a working tool for analysing sustainability and resource-management issues.

Contents

The course will cover:
• ecological foundations of sustainability, global change, the Anthropocene and planetary boundaries;
• Earth-system interconnections, ecosystem services, natural capital and environmental pressures generated by production systems;
• sustainable use of resources, including renewable resources, non-renewable resources, primary and secondary resources;
• plant biomass as renewable feedstock for bioenergy and bioproducts, including valorisation pathways, circular economy and cascading use;
• abiotic and non-renewable resources, including availability, supply risk, criticality, environmental impacts, resource efficiency and circularity;
• life cycle assessment, footprints and supply-chain assessment in relation to relative and absolute sustainability concepts;
• international policies linking planetary boundaries, resource use, circular economy and sustainability;
• interdisciplinary case studies on sustainable resource management across ecological, renewable and non-renewable resource perspectives.

Detailed program

• Geological time and the Anthropocene debate.
• Earth System, ecological complexity and interconnections among lithosphere, atmosphere, biosphere, hydrosphere and anthroposphere.
• Limits, tipping points, environmental surprises and planetary boundaries.
• Doughnut economy, sustainability concepts and links with the UN 2030 Agenda.
• Ecosystem services, natural capital, ecological footprint and links with LCA-based approaches.
• Overview of renewable and non-renewable resources in production and consumption systems.
• Biomass as renewable feedstock in the bioeconomy and its direct or indirect plant origin.

• Principles of plant biology and ecology relevant to biomass production and sustainable use.
• Classification of biomass by origin, generation, composition, availability and sustainability.
• Biomass feedstock types: dedicated crops, agricultural residues, forestry biomass, agro-industrial by-products and organic waste streams.
• Chemical components of biomass relevant for high-value compounds, bioenergy and bioproducts.
• Biomass valorisation pathways and conversion processes: thermochemical, biological and physical routes.
• Key biomass parameters for selecting conversion technologies.
• Circular economy and cascading principles for biomass and organic residues.
• Definition of abiotic resources and raw materials; availability, supply risk and demand in key sectors and technologies.
• Distribution of elements across environmental compartments and (anthro)biogeochemical cycles.
• Sustainable mining activities and global challenges in non-renewable resource management.
• Resource efficiency, circularity, reduce-reuse-recycle strategies, recycling, downcycling and upcycling.
• Urban mining and challenges associated with recycling and reuse of metals and other materials.
• Environmental impacts associated with extraction, use, processing and waste management of abiotic resources.
• Novel entities and pollution-related externalities.
• Introduction to life cycle assessment and footprint approaches to supply-chain assessment.
• Applications and limitations of LCA in sustainable resource management.
• Relative and absolute sustainability: linking LCA, footprints and planetary boundaries.
• Overview of EU and international policies for sustainable resource management and supply-chain assessment.
• International cooperation and global governance of sustainable resource management.
• Interdisciplinary case studies on biomass, non-renewable resources and production impacts within planetary boundaries.

Prerequisites

• Basic understanding of environmental science;
• Basic understanding of sustainability concepts;
• Basic notions of biology, ecology, chemistry and economic systems are useful for following the interdisciplinary contents of the course.

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 with activities shared by the three modules to support integration among ecological, renewable-resource and non-renewable-resource perspectives., Mixed Didactics, / Seminar.

Attendance to lectures and interactive exercises is highly recommended.

Textbook and teaching resource

• Slides and notes shown during lectures;
• Scientific articles, technical reports, policy documents and additional material made available on the e-learning

website of the course;
• Selected international reports and textbooks on global resource use, sustainability, circular economy, life cycle assessment and sustainable resource management, such as:
• 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.
• Nandabalan, Y.K., et al. (ed.). Zero waste biorefinery. Springer, 2022.
• 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
• Velasco-Munoz J.F., C.M. (2021) Sustainable Resource Management: Modern Approaches and Contexts. Elsevier ISBN: 9780128243428
• World Economic forum (2025) 2025 Global risk report https://www.weforum.org/publications/global-risks-report-2025/

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 exam could include in-group activities focusing on the presentation and discussion of assigned case studies.

The assessment will evaluate the student’s ability to understand and integrate the knowledge acquired in the three modules, critically discuss case studies, use appropriate scientific terminology, and provide a reasoned evaluation in relation to planetary boundaries and the 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:
• knowledge and understanding;
• ability to connect different concepts;
• autonomy of analysis and judgement;
• 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 | LIFE BELOW WATER | LIFE ON LAND