UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Economics of Carbon Sequestering

2627-2-F7603Q027-F7603Q02702

Aims

This course is part of the Laboratory Towards carbon negativity, an interdisciplinary program that integrates chemistry and economics to analyse the feasibility and sustainability of carbon capture technologies.
This module of the course aims to provide students with a comprehensive understanding of the economic principles, policy frameworks, and market mechanisms underpinning the development and deployment of Carbon Capture and Storage (CCS) technologies. CCS is increasingly recognized as a critical component of net-zero transition strategies, particularly in hard-to-abate industrial sectors and for the delivery of negative emissions.
The course examines CCS from an economic perspective, focusing on investment decisions, cost structures, regulatory incentives, carbon pricing mechanisms, and the role of CCS within broader energy and climate policies. Particular attention is devoted to the interaction between CCS, carbon markets, renewable energy deployment, industrial competitiveness, and long-term decarbonization pathways.
By combining economic theory with real-world case studies from Europe and other leading jurisdictions, the course enables students to critically evaluate the opportunities, limitations, and policy challenges associated with large-scale CCS deployment.
Learning Objectives

Upon successful completion of the course, students will be able to:

- Understand the role of CCS in climate change mitigation and net-zero strategies, including its applications in power generation, industry, and carbon dioxide removal.
- Analyze the economics of CCS projects, including capital and operating costs, transport and storage infrastructure, economies of scale, and learning effects.
- Evaluate investment decisions under uncertainty, considering carbon price volatility, regulatory risks, and long-term market expectations.
- Assess the effectiveness of policy instruments supporting CCS deployment, including carbon pricing, emissions trading systems, carbon contracts for difference (CCfDs), subsidies, tax credits, and regulatory mandates.
- Compare CCS with alternative decarbonization options, such as renewable energy, electrification, hydrogen, and energy efficiency measures, using economic and policy evaluation frameworks.

- Understand the economics of CO? transport and storage networks, including infrastructure planning, natural monopoly issues, and business models for shared CCS hubs and industrial clusters.
- Examine the role of CCS in industrial competitiveness and energy transition policies, with particular reference to the European Union and the EU ETS.
- Critically discuss the economic and ethical implications of negative emissions technologies, including BECCS and Direct Air Capture with Storage (DACCS).
- Apply economic tools and quantitative methods to assess CCS projects and policy scenarios.
- Develop evidence-based policy recommendations concerning the role of CCS within sustainable energy and climate strategies.

Contents

1. CCS and the Economics of Climate Change (4 hours)
2. Economics of the CCS Value Chain (8 hours)
3. Carbon Markets, Regulation and Policy Support (6 hours)
4. CCS, Competitiveness and Industrial Decarbonization (6 hours)
5. Negative Emissions, Future Perspectives and Case Studies (6 hours)

Detailed program

Module 1

Climate Change Economics and the Role of CCS (4 hours)

Lecture 1.1. Climate Change and Decarbonization Challenges (2 hours)
Topics:

- Climate change as a global externality
- Market failures and carbon emissions
- Social cost of carbon
- Net-zero targets and carbon budgets
- Hard-to-abate sectors
- Why mitigation alone may not be sufficient
  Key concepts:
- Externalities
- Pigouvian taxation
- Carbon pricing
- Marginal abatement cost
  Case study:
- EU Climate Law and 2050 climate neutrality objective

Lecture 1.2. Why CCS? Economic Rationale and Policy Debate (2 hours)
Topics:

- Historical evolution of CCS
- CCS in IPCC scenarios
- Role of CCS in net-zero pathways
- CCS versus renewable-based decarbonization
- Criticisms and controversies

- CCS and energy security
  Discussion:
  "Can Europe achieve climate neutrality without CCS?"

Module 2

Economics of the CCS Value Chain (8 hours)
Lecture 2.1: Capture Technologies and Cost Structure (2 hours)
Topics:

- Post-combustion capture
- Pre-combustion capture
- Oxy-fuel combustion
- Industrial CCS applications
  Economic analysis:
- CAPEX
- OPEX
- Energy penalty
- Cost of CO? avoided versus cost of CO? captured
  Indicators:
- Levelized Cost of Carbon Capture (LCOC)
  Exercise:
  Comparison of capture costs across sectors.

Lecture 2.2: Transport and Storage Economics (2 hours)
Topics:

- Pipeline transport
- Shipping of CO?
- Geological storage options
- Storage site characterization
  Economic issues:
- Economies of scale
- Network externalities
- Natural monopoly characteristics
- Infrastructure planning
  Case studies:
- Northern Lights
- Porthos
- Acorn

Lecture 2.3: Infrastructure Networks and Industrial Clusters (2 hours)
Topics:

- Shared transport infrastructure
- CCS hubs and clusters
- Industrial symbiosis
- Regional planning
  Economic questions:
- Cost allocation
- Access regulation
- Third-party access
  Case study:
  North Sea CCS clusters

Lecture 2.4: Cost Assessment and Project Evaluation (2 hours)
Topics:

- Cost-benefit analysis
- Discounting
- Net Present Value
- Internal Rate of Return
  Applications:
- Evaluation of CCS investments
- Sensitivity analysis
- Scenario analysis
  Practical exercise:
  Financial evaluation of a CCS project.

Module 3
Carbon Markets, Regulation and Policy Support (6 hours)

Lecture 3.1: Carbon Pricing and the EU ETS (2 hours)
Topics:

- Economic foundations of emissions trading
- Evolution of the EU ETS
- Carbon price formation
- Free allocation and CBAM
  Questions:
- When does the EU ETS make CCS profitable?
- Break-even carbon prices
  Exercise:
  Estimating CCS profitability under different EUA prices.

Lecture 3.2: Policy Instruments Supporting CCS (2 hours)
Topics:

- Investment subsidies
- Tax credits
- Carbon Contracts for Difference (CCfDs)
- Regulatory mandates
- Public procurement
  Comparative analysis:
- United States (45Q)
- European Union

Lecture 3.3: Risk Allocation and Regulatory Frameworks (2 hours)
Topics:

- Investment risk
- Regulatory risk
- Carbon price uncertainty
- Long-term storage liability
  Economic perspectives:
- Real options theory
- Public-private partnerships
- Regulated Asset Base models
  Case discussion:
  Who should bear CCS risks?

Module 4
CCS, Competitiveness and Industrial Decarbonization (6 hours)

Lecture 4.1: CCS for Heavy Industry (2 hours)
Topics:

- Cement
- Steel
- Chemicals
- Refineries
  Economic rationale:
- Process emissions
- Limited abatement alternatives
- Carbon leakage
  Case studies:
  European industrial CCS projects.

Lecture 4.2: CCS and Industrial Competitiveness (2 hours)
Topics:

- International competition
- Carbon leakage
- CBAM interactions
- Strategic autonomy
  Discussion:
  Can CCS preserve industrial competitiveness in Europe?

Lecture 4.3: CCS Compared with Alternative Decarbonization Strategies (2 hours)
Topics:

- Electrification
- Renewable energy
- Hydrogen
- Energy efficiency
  Methods:
- Marginal abatement cost curves
- Cost-effectiveness analysis
- Technology neutrality
  Group exercise:
  Ranking alternative mitigation options.

Module 5
Negative Emissions and Future Perspectives (6 hours)

Lecture 5.1: Bioenergy with Carbon Capture and Storage (BECCS) (2 hours)
Topics:

- Carbon removal economics
- Biomass markets
- Sustainability concerns
  Economic assessment:
- Cost per tonne removed
- Revenue opportunities

Lecture 5.2: Direct Air Capture and Storage (DACCS) (2 hours)

Topics:

- Technological characteristics
- Cost drivers
- Future cost reductions
  Discussion:
  Should governments subsidize DACCS?

Lecture 5.3
Future Business Models and CCS Scenarios (2 hours)
Topics:

- CCS in net-zero scenarios
- Future carbon markets
- Negative emission credits
- Emerging business models
  Final discussion:
  "The future role of CCS in sustainable development."

Prerequisites

Introductory microeconomics
Analytical methods

Teaching form

The course adopts an interactive teaching approach that combines lectures, literature-based seminars, quantitative exercises, and collaborative case-study analysis.
The course comprises 30 hours, organized into:

11 two-hour lectures (22 hours), delivered in person through traditional classroom teaching;
2 two-hour seminars (4 hours), dedicated to the reading and discussion of scientific papers, policy reports, and selected case studies;
2 two-hour case-study workshops (4 hours), during which students work in groups on the economic assessment of CCS projects, policy instruments, and investment decisions, followed by plenary discussion and presentation of results.

Textbook and teaching resource

- Lynne Lewis, Thomas Tietenberg, Environmental Economics and Policy, 2020, Routledge, (selected chapters).
- IPCC Special Report on Carbon Dioxide Capture and Storage
- Lecture slides, notes, and additional scientific articles provided on the e-learning platform.

Semester

First semester

Assessment method

The final assessment consists of a single oral examination at the end of the course. The examination is graded on a scale from 18/30 to 30/30 cum laude and covers all topics discussed during the course. Particular emphasis is placed on the student's ability to establish connections between economic concepts, policy instruments, market mechanisms, and real-world CCS applications, demonstrating a critical understanding of the role of Carbon Capture and Storage within sustainable energy and climate strategies.

The final grade is based on the overall assessment of the following criteria:

1. Knowledge and understanding of economic concepts and policy frameworks related to CCS
2. Ability to apply economic reasoning and analytical tools to CCS-related problems and policy scenarios
3. Communication and argumentation skills
4. Critical thinking and capacity to integrate economic, environmental, and policy perspectives

Grade below 18/30
Knowledge and Understanding: The student demonstrates only a partial understanding of the fundamental economic concepts and policy frameworks discussed during the course. Connections among concepts are fragmented and poorly supported by theoretical knowledge.
Ability to Apply Knowledge and Understanding: The student identifies only a limited number of relevant economic factors and is unable to integrate them into a coherent analysis of CCS-related issues.
Communication and Argumentation Skills: The student develops a weak and poorly structured argument, characterized by significant inaccuracies and limited use of appropriate terminology.
Critical Thinking and Integration Skills: The student shows limited ability to critically evaluate CCS policies, investments, and market mechanisms, and struggles to connect theoretical concepts with practical applications.

Grade 18–22/30
Knowledge and Understanding: The student demonstrates a basic understanding of the main economic principles, policy instruments, and market mechanisms relevant to CCS, although some inaccuracies may remain.
Ability to Apply Knowledge and Understanding: The student is able to identify several relevant elements of a CCS-related problem and provide a partially coherent analysis, while still exhibiting some weaknesses in economic reasoning.
Communication and Argumentation Skills: The student presents a basic but understandable argument, with an acceptable structure and use of economic terminology, despite occasional inaccuracies.
Critical Thinking and Integration Skills: The student demonstrates a basic ability to connect theoretical concepts with policy and market applications, although the analysis remains largely descriptive.

Grade 23–27/30
Knowledge and Understanding: The student demonstrates a solid understanding of the economic foundations of CCS, including cost structures, investment incentives, carbon pricing mechanisms, and regulatory frameworks. Explanations are generally accurate and supported by appropriate theoretical references.
Ability to Apply Knowledge and Understanding: The student effectively applies economic concepts and analytical tools to evaluate CCS projects, policies, and market developments, although methodological rigor may not always be fully developed.
Communication and Argumentation Skills: The student develops a coherent and well-structured argument, using appropriate economic terminology and demonstrating good communication skills.
Critical Thinking and Integration Skills: The student critically evaluates alternative policy options and demonstrates the ability to integrate economic, environmental, and regulatory perspectives in the assessment of CCS

deployment.

Grade 28–30/30 cum laude
Knowledge and Understanding: The student demonstrates an excellent and comprehensive mastery of the economic and policy dimensions of CCS, articulating complex relationships among technology costs, market incentives, regulatory frameworks, and climate objectives. Theoretical concepts are used rigorously and appropriately.
Ability to Apply Knowledge and Understanding: The student applies economic methods with a high degree of analytical rigor, providing comprehensive and well-supported evaluations of CCS investments, policies, and market outcomes.
Communication and Argumentation Skills: The student presents clear, persuasive, and logically rigorous arguments, demonstrating excellent command of economic terminology and concepts.
Critical Thinking and Integration Skills: The student exhibits advanced critical thinking skills, independently evaluating competing perspectives on CCS deployment and developing sophisticated analyses that integrate economic efficiency, environmental effectiveness, and policy feasibility.

The award of cum laude is reserved for students who demonstrate outstanding mastery of the subject, exceptional analytical ability, and an advanced capacity for critical and independent reasoning.

Office hours

Tuesday h15 (also by appointment in other dates/hours or online)
Building U6, 3rd floor, Room 3076

Sustainable Development Goals

QUALITY EDUCATION | AFFORDABLE AND CLEAN ENERGY | INDUSTRY, INNOVATION AND INFRASTRUCTURE | CLIMATE ACTION