

# Carbon Capture, Utilization, and Storage

As the interest in carbon capture, utilization and storage (CCUS) continues to grow around the world, so does the need for qualified professionals with unique faculty to take on the challenge. Mines' CCUS graduate certificate program fills that need. By bringing together our world-renowned knowledge in the earth sciences, engineering and economics and business fields, the CCUS program enables students to explore the unique challenges around carbon sequestration, climate change and the energy transition while acquiring the skills needed to advance their career.

Requirements to obtain a certificate in CCUS: Complete the Climate Change **and** the Energy Transition courses along with *either* the Geologic Storage *or* the Capture and Utilization courses.

## Degrees Offered

- Graduate Certificate in Carbon Capture, Utilization, and Storage

## Program description

The online CCUS certificate program is designed specifically for those wishing to strengthen their skills and deepen their knowledge base on Carbon Capture, Utilization, and Storage. Students can take the prescribed three courses to gain a graduate certificate in CCUS. All four courses can also be taken to count towards a graduate degree. The courses are online, of eight-week duration, and fully asynchronous.

Participants in this program can expect to:

- Assess data on climate change, and the effects of greenhouse gases on climate.
- Develop a solid foundation and proficiency in methods employed for the three aspects of carbon capture, utilization, and storage.
- Learn workflow and practices in the industry. Assess efficiency of CCUS practices.
- Develop skills to better communicate with colleagues in other disciplines in the organization.
- Learn and understand fundamental concepts from well-known faculty, experienced in the field.

## Options to Begin Program

Students must start the CCUS Certificate program with the Climate Change course or the Energy Transition course. Currently, the Climate Change is offered in First Online Session of fall Semester and the Energy Transition course is offered in First Online Session of spring Semester.

Examples of start dates and durations of the certificate program:

### Fall Start in mid-August:

1. Climate Change Course: mid-August to mid-October
2. CCUS course 1 (Geologic Storage or Carbon Capture): mid- October to mid-December
3. Energy Transition course: mid-January to mid-March
4. *Optional: CCUS course 2 (Geologic Storage or Carbon Capture): mid-March to mid-May*

### Spring Start in mid-January:

1. Energy Transition course: mid-January to mid-March
2. *Optional: CCUS course 1 (Geologic Storage or Carbon Capture): mid-March to mid-May*
3. Climate Change Course: mid-August to mid-October
4. *CCUS course 2 (Geologic Storage or Carbon Capture): mid- October to mid-December*

## PROGRAM DIRECTOR AND PROFESSOR

**Erik Menke**, Phone: 303-384-2781, E-mail: erik.menke@mines.edu

## COURSE COORDINATORS AND PROFESSORS

1. SYGN520: Climate Change and Sustainability: **Manika Prasad**
2. EBGN598D: Political Economy of the Energy Transition: **Ian Lange**
3. GPGN598AB: Geological Carbon Capture, Utilization, and Sequestration: **Ali Tura**
4. SYGN598C: Carbon Reduction: Capture and Utilization: **Anuj Chauhan**

## Carbon Capture, Utilization, and Storage

The Mines graduate certificate in Carbon Capture Utilization and Storage (CCUS) is a three-course, 9-credit, online program that provides graduate-level learning opportunities in climate and societal impacts of elevated levels of atmospheric CO<sub>2</sub>, quantitative assessment methods of CO<sub>2</sub> mitigation, as well as economic and policy analysis of a CCUS economy. By bringing salient aspects of CCUS under one umbrella, students gain and develop the knowledge and expertise to make informed decisions on CO<sub>2</sub> mitigation strategies, technologies, and can guide company and/or government policy and economic decisions.

The CCUS certificate program provides students with engaging learning experiences to understand and guide science-based discussions around climate change and how to assess it using environmental data and modeling methods, explore CO<sub>2</sub> capture and utilization technologies, and assess geologic utilization and sub-surface storage options. The program equips students with scientific knowledge about each CCUS topic and various technical CO<sub>2</sub> mitigation solutions and their risks. The program combines the expertise from our world-renowned graduate programs in Earth Sciences, Engineering, and Economics and Business and distills them into a certificate program on CCUS technologies and CCUS economy. This program is designed for professionals and recent graduates who want to acquire new skills for career advancement or get a head start on an advanced graduate degree. Courses in the program focus on real-world and current challenges and progress in CCUS techniques, and CCUS economics. The certificate program requires three 3-credit graduate courses identified below: two required courses and the option to choose an elective in either geologic or non-geologic CCUS.

### Required Courses

CCUS520	CLIMATE CHANGE AND SUSTAINABILITY	3.0
EBGN598	POLITICAL ECONOMY OF THE ENERGY TRANSITION	3.0

### Elective Course

CCUS521	GEOLOGICAL CARBON CAPTURE UTILIZATION AND SEQUESTRATION (CCUS)	3.0
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OR

SYGN598C CARBON REDUCTION: CAPTURE & UTILIZATION 3.0

**Course Modality:**

All courses are virtual and asynchronous - so students can listen to the lectures at convenience. All material is online and recorded for offline review. There are timed discussions and deliverables each week where students interact with their peers and with the instructors. The office hours are at specific times, but specific times to meet outside of those hours are often arranged depending on schedule conflicts or on geographic locations.

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**CCUS520. CLIMATE CHANGE AND SUSTAINABILITY. 3.0 Semester Hrs.**

This eight-week online course is intended to introduce students to effects of atmospheric CO<sub>2</sub> on climate, CO<sub>2</sub> mitigation and avoidance strategies, and aspects of ESG when considering mitigation strategies. The course will provide students with much needed working knowledge about effects of Greenhouse Gases (GHGs) using data, and models. It provides cause and effects of GHGs as well as potential solutions that are equitable and sustainable.

**Course Learning Outcomes**

- 1) Use professional communication methods; explain in written format to a non-scientific reader (general public or policy maker) the big picture of Climate Change and what is Climate Change
- 2) Use professional communication methods; communicate in written format to a non-scientific reader (general public or policy maker) the big picture of Climate Change considering the role of Carbon in climate change
- 3) Using professional communication methods, explain to a non-scientific reader the big picture of Climate Change considering How can we assess climate change - what's the science (to the level needed to explain to general public) behind understanding the causes, and modeling for predictions
- 4) Explain in written format to a non-scientific reader (general public or policy maker) how scientists and engineers are studying solutions to climate change.
- 5) Analyze and accurately discuss the analysis of data sets related to climate change and CCUS considering data sources, data errors and uncertainties, and selecting accurate and appropriate data
- 6) Balance the atmospheric carbon budget in a proposed CCUS plan; consider CCUS with an ESG perspective
- 7) Discuss, using known scientific and social science perspectives, ethical considerations, societal impacts and issues of Climate Change and CCUS that should be considered as planning CCUS
- 8) Analyze maps of climate vulnerability; discuss climate equity; assess scientific accuracy of climate maps

**CCUS521. GEOLOGICAL CARBON CAPTURE UTILIZATION AND SEQUESTRATION (CCUS). 3.0 Semester Hrs.**

This course will cover sub-surface aspects of sustainable CCUS projects. Specifically, the topics covered will be geology of the subsurface appropriate for CCUS, how to create sustainable projects, the physics of CO<sub>2</sub> transport, injection and storage it's their modeling studies, practical aspects of CO<sub>2</sub> flooding, monitoring and verification methods including seismic, gravity and electromagnetic methods, and assessing CO<sub>2</sub> capacity and migration. Each week of the course is taught by experts in

the area from geology to engineering to geophysics and covers essential topics such as Class VI CCUS wells and EPA permitting, sustainable project development, to detailed physics such as CO<sub>2</sub> phase and flow in the subsurface.

**Course Learning Outcomes**

**CCUS525. BIOLOGICAL CARBON CAPTURE AND CONVERSION. 3.0 Semester Hrs.**

Plants, bacteria, and algae have evolved over billions of years to efficiently use sunlight to turn carbon dioxide and water into useful chemicals, a potential solution to the very real problem of climate change. How do they do this? How can we take advantage of these processes? And, how can we improve on them to find practical solutions to address climate change? The purpose of this course is to answer these questions by introducing students to bioconversion, nature's ability to convert CO<sub>2</sub> into other molecules. In this online, asynchronous course, students will work collaboratively in small teams to discuss current literature on carbon dioxide bioconversion, evaluate the effects of various parameters on bioconversion rates and efficiencies, and design and present case studies on ways to use plants, algae, and bacteria to convert CO<sub>2</sub> to useful material. Prerequisite: None Co-requisite: None Prerequisite: Undergraduate introductory biology course (BIOL300 and BIOL301, or equivalent), Undergraduate general chemistry course (CHGN121 and CHGN122, or equivalent).

**Course Learning Outcomes**

- 1) Analyze how plants, algae, and bacteria contribute to the carbon cycle
- 2) Analyze how plants, algae, and bacteria contribute to the carbon cycle
- 3) Analyze how plants, algae, and bacteria contribute to the carbon cycle
- 4) Evaluate the effect various parameters (such as temperature, pH, salinity, light, etc.) have on the ability of bacteria to convert CO<sub>2</sub> via photosynthesis
- 5) Recommend an appropriate biological-based method for capturing CO<sub>2</sub> and converting it to a biofuel, based on the needs and available resources of a stakeholder
- 6) Demonstrate the ability to productively contribute to a team evaluating biological methods for CO<sub>2</sub> capture and conversion
- 7) Develop and deliver a presentation on biological CO<sub>2</sub> capture and conversion catalysts to an audience of postgraduate engineers

**CCUS530. THE KINETICS OF CARBON DIOXIDE REACTIONS. 3.0 Semester Hrs.**

Carbon dioxide is an extremely stable molecule that stays in the atmosphere for hundreds of years. What makes it so stable? Why does it take so long to convert to something else? How can we, as scientists and engineers, use chemistry to turn carbon dioxide into other, useful things, like fuels and materials? The purpose of this course is to answer these questions by delving into the thermodynamics of carbon dioxide, the kinetics of CO<sub>2</sub> reactions, and how electrochemistry, photochemistry, and catalysts can overcome these problems. In this online, asynchronous course, students will work collaboratively in small teams to discuss current literature on CO<sub>2</sub> conversion reactions, evaluate the pros and cons of electrochemistry and photochemistry for CO<sub>2</sub> conversion, and design and present case studies on ways to use electrocatalysts and photocatalysts to convert CO<sub>2</sub> to useful materials. Prerequisite: None Co-requisite: None Prerequisite: Undergraduate introductory chemistry (CHGN121 and CHGN122, or equivalent), Differential equations (MATH225 or equivalent).

**Course Learning Outcomes**

- 1. Propose electrochemical experiments, and interpret the resulting data, that would allow you to differentiate between CO<sub>2</sub> reaction mechanisms
- 2. Propose photochemical experiments, and interpret the resulting data, that would allow you to differentiate between CO<sub>2</sub> reaction mechanisms
- 3. Explain the underlying thermodynamic problems associated with converting CO<sub>2</sub> into other carbon-based chemicals.
- 4. Evaluate CO<sub>2</sub> conversion catalysts, based on various methods such as selectivity, turnover, activity, and cost
- 5. Evaluate CO<sub>2</sub> reaction mechanisms based on experimental data
- 6. Develop and deliver a presentation on CO<sub>2</sub> conversion catalysts to an audience of postgraduate engineers
- 7. Demonstrate the ability to productively contribute to a team evaluating CO<sub>2</sub> conversion catalysts

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**EBGN598. POLITICAL ECONOMY OF THE ENERGY TRANSITION. 3.0****Semester Hrs.**

This course provides an overview of economics, business, and political topics that are commonly found in the energy transition. Many of the assignments relate back to skills that are needed to interact with economics, business, and policy professionals. The course is designed for students with little, if any, social science or business training. Students will build a basic knowledge of economics, finance, and business issues that are relevant to energy markets and industries.

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**SYGN598. CARBON REDUCTION: CAPTURE & UTILIZATION. 3.0****Semester Hrs.**

This course provides an overview of the technologies used for decarbonization with an introduction to the chemistry of the molecule and the reactive CO<sub>2</sub> capture technologies, carbon capture and separation technologies, thermodynamics, and practical applications from a CCUS systems development perspective.