COURSE SYLLABUS: Carbon Dioxide Removal Technologies, Spring 2023

Course Information:	Instructor Contact Information
CHE 418 Spring 2023	Dr. Amanda Simson
Monday 4 - 4:50 pm (Room 106 and Zoom for guest speakers)	Room 418, (212) 353-4373
Wednesday 10 - 11:50 am (Room 101)	Email: amanda.simson@cooper.edu
Course website: Teams	Office Hours: Mondays 1-2 pm (virtual), Wednesdays 1-2 pm

Course Description
Survey of the field of Carbon Dioxide Removal (CDR) technologies. Review of models that estimate carbon removal amounts to meet international climate goals. Basics of existing adsorption technology and design of industrial CDR plants. Evaluation of biomass-based CDR solutions: afforestation, biochar, and Bioenergy with Carbon Capture and Storage (BECCS). *3 credits*

Prerequisite (required): ChE232 or ESC-330 (Thermodynamics I)
Preference (preference): ChE332 (Reaction Engineering)

Course Objectives
The goal of this course is for students to understand the growing field of Carbon Dioxide Removal (CDR) technologies using fundamental Chemical Engineering knowledge. Students will compare and contrast these technologies from angles including technical feasibility, cost, and impacts on biodiversity and human health and wellbeing. Additionally, students will learn how to perform research in a new and rapidly growing field, using scientific literature. Specifically, by the end of the course, students should be able to:

1. Understand the different estimates for necessary carbon removal by identifying assumptions in global climate models like integrated assessment models (IAMs).
2. Compare proposed CO2 utilization and removal strategies using metrics like cost, scalability, permanence, environmental impact.
3. Describe the common physical and chemical adsorbents used for CO2 capture and explain why they are good adsorbents.
4. Compare common techniques for CO2 desorption.
5. Recommend operating conditions for different types of adsorbents using data from the scientific literature.
6. Describe the currently proposed or in-use biomass-based CDR technologies.
7. Evaluate a biomass-based plant design using common life cycle assessment metrics.
8. Calculate total potential carbon removal for different enhanced weathering reactions.
9. Evaluate a specific CDR project using common CDR metrics like cost, feasibility, scalability, permanence, environmental impact.

Learning Objective Assessment Plan

- Reading response assignments and/or problem solving assignments (LOs 1-5) (25%)

- Take home midterm examination covering: terminology and basic concepts, overview of technologies and common metrics of analysis, DAC: common adsorbents, kinetic and thermodynamic considerations for CO_2 adsorption and absorption, strategies for desorption (LOs 1-5) (25%)
- Presentation assignment (group) on cost and environmental impact for a specific CDR project (LO 6) (15%)
- Final poster project exploring a question, not yet answered in the literature, on a specific CDR technology (30%)
- Participation in class discussions and attendance (5%)

Course Format

There are four primary sections of the course: Introduction to CDR and methods, nature-based solutions, biomass based technological solutions, and the Chemical Engineering of Carbon Dioxide Removal. We will also focus on current CDR projects (student presentations) and on unanswered questions in this growing field (final presentation). There will be extensive reading compared to typical engineering courses, and associated reading responses and discussion in class, in addition to standard problem solving. There will be one take home exam. The class meets twice per week in person but a course zoom link is provided, particularly for guest speakers during the Monday course. Teams will be used for course communications, posting readings, and posting and grading of assignments.

Expectations of the Student

- Do your best to participate and to complete assignments with care, thoroughness, and creativity.
- Communicate issues that are affecting your class performance with the instructor.
- Attend and actively participate in class. Excused absences should be discussed with me prior to class time except in emergencies. Lateness and missed classes will count towards your participation grade.
- Treat instructor and other classmates with respect.
- Be yourself, be creative, have fun, and help create a good learning environment for everyone

Expectations of the Instructor

- I will keep an updated and posted schedule. As this is a new class, there may be changes in the curriculum as we go. I will do my best to communicate these changes with you.
- I will work with you to find projects and problems of interest to you. I hope that the class is a place for you to be creative and develop independent ideas and to participate in the field of CDR.
- I hope to make all students feel respected and recognized in this course. Please chat me or email me about any class issues that arise.

Required Text

1. CDR Primer available free online (J Wilcox, B Kolosz, & J Freeman (2021) *CDR Primer)*
2. Report by the National Academies of Sciences on *Negative Emissions Technologies and Reliable Sequestration: A Research Agenda* available free online (https://doi.org/10.17226/25259).
3. Reference basic thermodynamics text and reaction engineering text

Other assigned readings will be provided as needed via Teams and in the course schedule. Additionally, a good resource is the open air collective which hosts relevant weekly talks on Zoom. This may be particularly helpful for project work: https://openaircollective.cc/

Special Accommodations

Students with disabilities or needing special accommodations should email me and meet with me within the first two weeks of the semester to discuss accommodations. More information on disability support services at Cooper can be found here: https://cooper.edu/students/student-affairs/disability

Mental Health and Wellbeing

Your mental health and wellbeing is more important than your performance in this class. If issues arise where you feel like your health is being compromised, please speak to me and/or seek support through the Cooper's Counseling and Mental Health Support Services: https://cooper.edu/students/student-affairs/health/counseling

Academic Honesty

Plagiarism will not be tolerated. According to the Cooper Union course catalog, plagiarism is "the presentation of another persons 'work product' (ideas, words, equations, computer code, graphics, lab data, etc.) as one's own."

Course Outline/Schedule

Below, see the preliminary course outline and schedule. Again, since this is a new elective course, there may be some changes to the organization of course content as the semester progresses.

Updated: Amanda Simson, January 25, 2024

PRELIMINARY COURSE SCHEDULE

Week 1	• Review of prerequisite knowledge and terms • Development of glossary and map of knowledge • Brief overview of CDR categorization and brief introduction to methods • Understand the different estimates for necessary carbon removal • Introduction of BECCS and DAC Reading: CDR Primer 1.0-1.5, Wired Article Assignment: Glossary, Map of Knowledge, Prerequisite knowledge assignment, Reading response
Week 2	• Larger impacts of CDR –social and climate justice • Overview of other methods: Enhanced Weathering (land) and Ocean Alkalinity Enhancement, Introduction of nature-based solutions (afforestation vs reforestation, coastal methods vs geoengineering), Biochar and other waste carbon storage techniques Reading: CDR Primer 1.6 and 1.7, White Cliffs of Dover
Week 3-4.5	• Intersection of CDR and impacts on Planetary Boundaries • Comparing CDR technologies using LCA and metrics for permanence, scalability, environmental impacts National Academies of Science Report Chapter 6, Article on Biodiversity Assignment: Reading response, presentation decisions
Week 4.5-8	• Direct Air Capture – DAC • Introduction to adsorption process • DAC vs CCS – thermodynamic and kinetic analysis • Adsorption vs absorption • Design of adsorbents • Kinetics of adsorption and desorption reactions • Thermodynamics of adsorption and desorption reactions Read National Academies of Science Report Chapter 5, CDR Chapter 2, AIChE adsorption basics, DAC Review Article; LCA of direct air capture; Assignment: Reading Response and Problem Solving
Week 9-10.5	• Carbon dioxide and carbon utilization • Thermochemical processing of biomass

	• Comparison of waste biomass technologies for CDR • Project work • Midterm Take Home
Week 10.5-11	• Enhanced weathering on land • Enhanced weathering at sea • Carbon mineralization paired with DAC systems
Week 12-13	Project work
Week 14	Project work and critique
Week 15	Final projects