ME498/598 Carbon Capture and Storage

Instructor: Jiajun He

Spring 2024

Class Contents:

Part I Carbon Capture:

Thermodynamics/kinetics of chemical capture
Carbon capture from the industrial sector and power sources
IGCC, oxy-fuel combustion, and chemical looping
Reliable storage options
Carbon dioxide removal from the atmosphere

Part II Carbon Sequestration:

Fundamentals of Carbon Sequestration
Injection Methods and Pressure Buildup
Modeling Fate and Transport
Sequestration Capacity Assessment
Health Safety and Environmental Risks of Sequestration
Monitoring CO_2 Storage
Cost of sequestration and institutional issues

Skills You Will Acquire:

Minimum and real work calculations
2nd-Law efficiency calculations
Evaluation of tradeoffs between capture technologies
Running IECM Capture Economic Model
Assessment of the potential of CCS for global CO_2 emissions reduction
Estimates of CO_2 saturation and migration after injection
Evaluation of CO_2 storage potential
Awareness of CO_2 storage risks as well as monitoring and mitigation methods

Class Meetings:

On-Campus Sections: Mon, Wed and Fri 10:00 am – 10:50 am at 403B2 Engineering Hall.

Online Sections: Lecture recording will be provided after class.

You are expected to attend every class session or watch the lecture recording.

Office hours: If some aspect of the course material is unclear to you after independent study, you are expected to raise the issue in class or during office hours.

Prof. Jiajun He <jiajunhe@illinois.edu> , **Mondays 2:00 pm – 3:00 pm** and by appointment in 2026 LuMEB

TA: Sadman Sakib < ssakib2@illinois.edu>, time and location TBA

Questions can also be posted on the Piazza site: https://piazza.com/class/lr8lf0p3p8e57/

Text and Notes:

Part 1: **Carbon Capture** by Jennifer Wilcox (Springer, 2012)
Part 2: Lecture notes and supplemental reading

Homework: Problem sets (x6) and writing assignments (x2, for 4-hour sections only) will be assigned throughout the semester. The due date will be announced when the assignment is made. Late homework will not be accepted, unless you make prior arrangements with the instructor (or for a medical emergency). When a homework set involves computer analysis, do not submit a printout alone as your solution. The printout may be part of your solution; however, your approach must be clearly explained and independent of the program listing.

Exams: There will be a one midterm exam and one final exam to be announced later in class. Both exams will be take-home exams, where you will be allowed 48 hours to complete them. Make-up exams will only be permitted by prior arrangement and only for reasons described in the U of I Student Code.

Software: The main computer tool we will use is Integrated Environmental Control Model (IECM). IECM is a tool for calculating the performance, emissions, and cost of a fossil-fueled power plant, developed by Carnegie Mellon University and Department of Engineering & Public Policy. You will need to download the software at https://uwyo.edu/iecm/download-iecm.html. Video Tutorials can be accessed at https://www.uwyo.edu/iecm/videos/.

Grades: Course grades for the 3-hour option will be based on the problem sets, the midterm exam, and the final exam according to the following scheme:

- Problem Sets 40%
- Midterm Exam 30%
- Final Exam 30%

Course grades for the 4-hour option will be based on the problem sets, the writing assignments, the midterm exam, and the final exam according to the following scheme:

- Problem Sets 20%
- Writing Assignments 20%
- Midterm Exam 30%
- Final Exam 30%

Final letter grades will be assigned based on the scale below.

Letter Grade	*Final Course Average*
A+	97 – 100
A	94 – 96
A-	90 – 93
B+	87 – 89
B	84 – 86
B-	80 – 83
C+	77 – 79
C	74 – 76
C-	70 – 73
D+	67 – 69
D	64 – 66
D-	60 – 63
F	0 – 59

For final grades that are very close to the cutoff lines (**less than 0.5 below the cutoff**, e.g., 96.5, 93.5, …), the upper letter grade will be given. The instructor has no predetermined 'target' grade distribution, and the distribution can vary significantly from semester to semester.

Academic Integrity: Violations of University policy with respect to academic integrity will not be tolerated and infractions may lead to suspension or dismissal from the University. See: http://admin.illinois.edu/policy/code/article1_part4_1-401.html

Campus Safety: Important information regarding Campus Safety and General Emergency Response are available at http://illinois.edu/emailer/newsletter/39474.html. Please take some time to review these documents.

Course Schedule (Tentative)

	Day	Date	Assignments	Topics	Reading
1	Wed	1-17		First Day of Class Introduction to Carbon Capture	
2	Fri	1-19		Introduction to Carbon Capture CO_2 Utilization	Wilcox 2012 Chapter 1
3	Mon	1-22		Minimum work, Separation process overviews Minimum work example problem	
4	Wed	1-24	PS #1 Posted	Carbon Capture Processes (Post, Pre, Oxy) Absorption, Gas/liquid diffusion, Henry's Law	Wilcox 2012 Chapter 3
5	Fri	1-26		Modified Henry's Law Coefficient, Liquid-Phase Diffusivity, CO_2-Water, CO_2-amine Reactions	
6	Mon	1-29		Film Theory, CO_2 Absorption Rate, Real Work Calculations	
7	Wed	1-31	PS #1 Due	Intro to Adsorption, Physisorption/Chemisorption Lennard-Jones, Isotherms	Wilcox 2012 Chapter 4
8	Fri	2-2	PS #2 Posted	Isotherm Types, Langmuir and BET Isotherms Intro to different Sorbents, Activated Carbon	
9	Mon	2-5		Zeolite, MOF, Example Problem - Film Model, Example Problem - Langmuir Isotherm	
10	Wed	2-7		Mass Transport During Adsorption, Breakthrough Curves, Molecular Simulations	
11	Fri	2-9		PSA vs TSA, Pressure Drop, Real Work Intro to Membrane Technology	
12	Mon	2-12	PS #2 Due	Membrane Selectivity, Single/Multistage Configurations, Membrane Modules	Wilcox 2012 Chapter 5
13	Wed	2-14	PS #3 Posted	Adsorption Example Problems	
14	Fri	2-16		Intro to Integrated Environmental Control Model (IECM)	
15	Mon	2-19		IECM Tutorial (cont.)	
16	Wed	2-21		Negative Emissions Technologies Direct Air Capture	
17	Fri	2-23	PS #3 Due	Watch Jennifer Wilcox, Katherine Hayhoe and Marshall Shepard's TED Talks – Online	
18	Mon	2-26	WA #1 Posted	Natural Solutions for Carbon Dioxide Removal	
19	Wed	2-28		CO_2 Conversion	Wilcox 2012 Chapter 8
20	Fri	3-1		Midterm Review	
21	Mon	3-4		CO_2 Mineralization	Wilcox 2012 Chapter 9
22	Wed	3-6		**Midterm**	

23	Fri	3-8		Watch Jaeson Cardiff, Bas Sudmeijer, and Steve Oldham's TED Talks – Online
	Mon	3-11		*Spring Break*
	Wed	3-13		*Spring Break*
	Fri	3-15		*Spring Break*
24	Mon	3-18		Fundamentals of CO_2 storage
25	Wed	3-20	WA #1 Due	Thermodynamic properties of CO_2
26	Fri	3-22	PS #4 Posted (3/24)	Pipeline transport of CO_2
27	Mon	3-25		Fundamentals of multi-phase flow of CO_2 and brine
28	Wed	3-27		Multiphase flow and CO_2 plume migration
29	Fri	3-29	PS #4 Due (4/2)	Injection pressure of single-phase water
30	Mon	4-1	WA #2 Posted PS #5 Posted	Injection pressure of *CO_2* into water reservoir
31	Wed	4-3		Reservoir seals (caprocks)
32	Fri	4-5		Secondary trapping mechanisms
33	Mon	4-8		Numerical simulation of storage efficiency and long-term fate of stored CO_2
34	Wed	4-10		Environment, health, and safety risks of CO_2 storage; risk management
35	Fri	4-12	PS #5 Due PS #6 Posted	Monitoring
36	Mon	4-15		Capacity assessment
37	Wed	4-17		Final Review 1
38	Fri	4-19		Final Review 2
	Mon	4-22	PS #6 Due	
	Thu	5-2	WA #2 Due	
	Thu-Fri	5-9 thru 5-10		**Take-Home Final Exam**