ACKNOWLEDGEMENT

UBC's Point Grey Campus is located on the traditional, ancestral, and unceded territory of the xwməθkwəy̓əm (Musqueam) people. The land it is situated on has always been a place of learning for the Musqueam people, who for millennia have passed on their culture, history, and traditions from one generation to the next on this site.

COURSE INFORMATION

Course Title	Course Code Number	Credit Value
Carbon Capture, Conversion and Sequestration Technologies	CHBE 488 / 588	3
Course Calendar Description		
Examination of carbon capture technologies, and CO_2 conversion and sequestration options. Technical foundations on carbon cycle, thermodynamics, transport, absorption, adsorption, sequestration, process control, mineralization and conversion. Analysis of cases in the context of technology, policy and regulatory framework.		
Course Schedule M/W 15:00 – 16:30 T 16:30 – 18:00 (studio and case study work time, every other week starting from week 2) Reading week: Feb 19 – 23, 2024 (no class or studio)		

PREREQUISITES

One of CHBE 244, MTRL 252; and one of CHBE 251, CIVL 215, MTRL 263

CONTACTS

Course Instructor(s)	Contact Details	Office Location	Office Hours
Naoko Ellis	naoko.ellis@ubc.ca	CHBE 227	By appointment
Sergio Berretta	sergio.berretta@ubc.ca	CHBE 431	By appointment

COURSE INSTRUCTOR BIOGRAPHICAL STATEMENT

Naoko Ellis is a Professor in the Department of Chemical and Biological Engineering at the University of British Columbia (UBC). She holds a Ph.D. (UBC, 2003); M.E.Sc. (Western, 1993); and a B.Sc. (Honours, Waterloo, 1991).

Her expertise lies in the area of multiphase reaction engineering with emphasis on biomass utilization. Some current projects include: biomass gasification and pyrolysis; CO_2 capture, including chemical looping combustion; pyrolysis product utilization; and biofuels. She has worked on adding value to biomass residues through production of syngas, bio-oil upgrading and biochar development. Between 2015-2018, She served as the Senior Research Director of the Carbon Capture & Conversion Institute (CCCI), which is a collaborative partnership between CMC Research Institutes, the University of British Columbia and BC Research Inc. During the most recent sabbatical leave, she has been the interim dean of undergraduate faculty at the newly founded Fulbright University Vietnam, a liberal arts, science and engineering, not-for-profit University in Ho Chi Minh City, Vietnam.

https://www.chbe.ubc.ca/profile/naoko-ellis/
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Sergio Berretta (B.A.Sc., 1995) is a chemical engineer with over 25 years of industrial experience on the scale-up, de-risking, and detail engineering design of process technologies. For over a decade, Sergio worked in the design and commissioning of large chemical plants worldwide, with projects in four continents. For the last decade, Sergio has been working on the scale-up and de-risking of novel process technologies, including the detail design of pilot plants. He was the Chief Operating Officer of BC Research from 2013-2018 and was a founding executive of the Carbon Capture and Conversion Institute. Today he is an independent consultant working for a number of start-ups. He is also an adjunct professor at the University of British Columbia where he teaches engineering design of chemical and biological processes.

https://www.linkedin.com/in/sergioberretta/

COURSE NARRATIVE

It is widely accepted, by most, that carbon emissions have an effect on our environment, which has led to the accelerated development of a wide-range of technologies and schemes aimed at capturing those emissions. However, few of these technologies have yet been installed. A core question is, why? To start answering the question we need to first dissect and better define the problem, and critically evaluate the proposed solutions. Carbon emissions are not all the same. Each type of emission presents a different challenge with potential unique solutions. And each technical solution has its limitations and shortcomings. To fully understand the challenge, we need to first learn to separate facts from opinions, and to frame those facts within the wider possible context of the problem definitions and potential solutions, not necessarily through the narrow narrative that carbon emitters and/or technology solution providers often state to make their cases. We need to learn to think critically.

In this course, we will use Carbon Capture, Conversion and Sequestration (CCCS) as the technical field to understand and learn the approach, mindset and skills that are required to better define the different carbon emissions, and to evaluate proposed technological solutions. We will learn to evaluate the problems and solutions critically, looking for connectivity between the two, even when there may be incomplete information. We will learn in collaboration with others (potentially from different disciplines, and vertical integration, i.e., undergrad and grad), examine our assumptions, and practice reflection to cultivate ways in becoming a practicing engineer.

This is a case study based course where you will practice the technical foundations that you will learn through the term. For the academic year of 2024-2025, we have developed two cases based on:

- Carbon Conversion Technology from Twelve
- Carbon Capture from Leilac

COURSE STRUCTURE

The course is divided into six interwoven modules:

- Module 1: Introduction to carbon cycle and context
- Module 2: Technology assessment tool box: systems approach; streamlined technoeconomic analysis; streamlined life cycle analysis
- Module 3: Carbon capture and conversion technologies
- Module 4: Transportation and sequestration
- Module 5: Policy framework
- Module 6: Synthesis and wrap-up

CHBE 488 588 is a blended course. Each week you are required to go through the "prep" (may include reading and/or viewing of videos to then complete a readiness assurance quiz (RAQ)), attend a 90 minute class (Class A), complete studio work (90 minute, bi-weekly), attend a second 90 minute class (Class B), and finally, write periodic reflections on what you are learning.

Online prep
- prep (readings, video viewing, etc.)
- readiness assurance quiz (RAQ)

Class A Mondays
- discussions and learning activities

Studio Tuesdays
- bi-weekly
- team work on case study

Class B Wednesdays
- discussions and learning activities

SCHEDULE OF TOPICS

Here is a tentative schedule for the course. If there are any changes to the schedule, you will be notified.

Modules	Week	Weekly Topics	Studio Topics
M1 Introduction to Carbon Cycle	**W1**	Introduction to: the context and structure of the course; global warming of 1.5°C challenge; understanding the numbers behind CCUS	
M2 Technology Assessment Tool Box	**W2**	Overview of CCUS technologies; systems thinking; systems mapping; circular economy	**S1** Intro to the case studies and Systems mapping
	W3	Intro to Technoeconomic Assessment (TEA)/Lifecycle Assessment (LCA)	
	W4	Estimating carbon equivalents	**S2** Case study framework

M3 Carbon Capture and Conversion Technologies	**W5**	Carbon capture: absorption, adsorption, direct air capture Carbon conversion: chemicals and fuels Carbon utilization: enhanced oil recovery, urea, other chemicals Emerging technologies	
	W6		**S3** Flowsheet and Mass and Energy Balances for the case studies
			SPRING BREAK
	W7		**S4** Carbon Balance
	W8		
	W9		**S5** Policy
	W10		
M4 Transportation and Sequestration	**W11**	CO_2 transportation	
	W12	Carbon sequestration	
M5 CCUS Policy framework	**W13**	CCUS* regulatory framework; carbon tax carbon markets	**S6** Showcase (grads)
M6 **Synthesis and wrap up**	**W14**	Wrap up	

*CCUS: Carbon Capture, Utilization and Sequestration

LEARNING OUTCOMES

By the end of the course, students should be able to:

- Set the framework to properly assess the technical and economic feasibility of a process technology
- Visualize and tackle process challenges from different perspectives to practice lateral thinking
- Work and find solutions using incomplete information
- Be critical of the information, data, and conclusions provided by others
- Evaluate the environmental footprint of CCCS technologies through preparing process flowsheets, carbon balances, and stream-lined life cycle analyses (LCA) framework
- Evaluate CCCS cases using technical, policy and regulatory frameworks
- Integrate systems thinking in analyzing the impact of CCCS technology in climate change scenarios
- Develop one's tolerance towards ambiguity and uncertainty through building technology narratives
- Cultivate one's communication skills and abilities towards working in teams and with the learning community
- Develop one's skills as a reflective practitioner through personal reflection throughout the course

LEARNING MATERIALS

No single textbook is assigned to this course.

For each module, there are mandatory preparatory materials (prep) to review (readings and/or video viewing, etc.). These will be posted on Canvas. Further suggested reading material is available on Canvas through the UBC library online reserve system (LORC). Some of the suggested references are as follow:

- Smit, B., Reimer, J.A., Oldenburg, C.M., Bourg, I.C. (2014) Introduction to Carbon Capture and Sequestration. Imperial College Press.
- Wilcox, J., (2012) Carbon Capture. Springer.

ASSESSMENTS OF LEARNING

Your course grade will be determined according to the following components:

Items	**CHBE 488**	**CHBE 588**	**Notes**
Technology knowledge	Readiness Assurance Quiz (RAQ) (individual) 6 % Technology lecture (12% in team; 3% individual) total 15%	Readiness Assurance Quiz (RAQ) (individual) 10% Technology lecture (12% in team; 3% individual) total 15%	Short quiz based on assigned readings: RAQ to be done online; Studio quiz in-class UG: top 6 RAQ marks GRAD: all RAQ marks to be included Demonstrate an in-depth understanding of the CCCS technologies and their potential impacts
Assignments	2 Assignments (individual) 10%	2 Assignments (individual) 10%	Demonstrate the ability to connect various concepts covered in course
Case analysis	in team 30%	in team 30%	Conduct technical and life-cycle based analyses of emerging technology
Team work based on peer evaluation*			iPeer is conducted twice (first a formative feedback from your team mates; second a summative feedback for adjusting team marks)
Learning journey reflections	7% (individual)	7% (individual)	Document one's learning journey (letter to self, ipeer comments, final reflection)

Final exam (Undergrads)	25% (individual)		Demonstrate knowledge of CCUS and their contextual issues Articulate a section from your case study (you must master your whole case study)
Showcase presentation (Grads)		11% (in team)	Final presentation (SME) on a chosen CCUS technology/process/instrument
Critical commenting (Grads)		10% (individual)	Critique on ChatGPT output on carbon management policy
Participation/facilitation/ leadership and contribution to the learning community	6% (individual)	6% (individual)	Contribute to class discussions, facilitations, online blog entries and peer learning support
	1% (individual)	1% (individual)	Mid-term iPeer feedback

*Peer evaluation

You evaluate your teammates' contributions and performance, while also being evaluated by your teammates. You use iPeer, which is an online peer evaluation tool. For each teammate (including yourself), you evaluate that person's performance to give a raw score and constructive comments. The peer evaluation criteria include professionalism, initiative, responsibility, and communication.

After the evaluation due date, you receive anonymous, randomly-ordered comments and ratings from your teammates. Outside of iPeer, scores given by each person are normalized to an average of 100. Your self-evaluation is for reference only and does not affect your final score. This way, differences in evaluation standards between individuals are removed. Similarly, you do not penalize yourself by giving your teammates high evaluations, nor do you benefit by giving your teammates low evaluations.

The final, normalized peer evaluation scores within a team will average 100% – i.e., some individuals will have higher and some lower. The team contribution to each individual's course grade is determined by multiplying the team grade by the individual's peer evaluation score. In total, there are two peer evaluation events, roughly evenly-spaced throughout the course.

Each peer evaluation event is open for one week. Late evaluations are accepted up to one week late.

Following the close of each peer evaluation event, you receive anonymous and randomly-ordered scores and comments from your teammates.

UNIVERSITY POLICIES

UBC provides resources to support student learning and to maintain healthy lifestyles but recognizes that sometimes crises arise and so there are additional resources to access including those for survivors of sexual violence. UBC values respect for the person and ideas of all members of the academic community. Harassment and discrimination are not tolerated nor is suppression of academic freedom. UBC provides appropriate accommodation for students with disabilities and for religious observances. UBC values academic honesty and students are expected to acknowledge the ideas generated by others and to uphold the highest academic standards in all of their actions.

Details of the policies and how to access support are available on **the UBC Senate website.**

During this pandemic, the shift to online learning has greatly altered teaching and studying at UBC, including changes to health and safety considerations. Keep in mind that some UBC courses might cover topics that are censored or considered illegal by non-Canadian governments. This may include, but is not limited to, human rights, representative government, defamation, obscenity, gender or sexuality, and historical or current geopolitical controversies. If you are a student living abroad, you will be subject to the laws of your local jurisdiction, and your local authorities might limit your access to course material or take punitive action against you. UBC is strongly committed to academic freedom, but has no control over foreign authorities (please visit http://www.calendar.ubc.ca/vancouver/index.cfm?tree=3,33,86,0 for an articulation of the values of the University conveyed in the Senate Statement on Academic Freedom). Thus, we recognize that students will have legitimate reason to exercise caution in studying certain subjects. If you have concerns regarding your personal situation, consider postponing taking a course with manifest risks, until you are back on campus or reach out to your academic advisor to find substitute courses. For further information and support, please visit: http://academic.ubc.ca/support-resources/freedom-expression

OTHER COURSE POLICIES

- Accessibility: UBC is committed to accommodating students with special needs in its instructional programs. If you have special needs, please meet with a the UBC Centre for Accessibility advisor to determine for what accommodations/services you are eligible. If you require special assistance or accommodations for this course, please contact me as soon as possible with your information from the UBC Centre for Accessibility (https://students.ubc.ca/about-student services/centre-foraccessibility).
- Religious observance: You will not be penalized because of observances of your religious beliefs. Whenever possible, you will be given reasonable time to reschedule any academic assignment that is missed due to participation in a religious observance. You are responsible for informing me of any intended absences for religious observances in advance.
- Academic integrity: You must follow UBC's policy on plagiarism and other forms of academic misconduct and are responsible for familiarizing yourself with UBC's campus-wide policy on "Academic Misconduct" (http://www.calendar.ubc.ca/vancouver/?tree=3,54,111,959). For further information, see https://learningcommons.ubc.ca/academic-integrity/.
- Use of Generative AI Tools: If you make use of generative artificial intelligence tools to complete any project deliverables or other course-related work, the generated material must be clearly and correctly indicated, and cited/referenced using APA referencing style for generative AI. Failure to clearly indicate and reference AI-generated material will be reported as academic misconduct. Please consult your Instructor if you have any questions about the use of generative AI tools.

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