Syllabus
CHE 150: Climate Engineering for Global Warming

Semester: Fall or Spring
Credit Hours: 3.00
Instructor: Meenesh Singh

Purpose of the Course

This is a general education course under the General-Education Core category of "Analyzing the Natural World" and "Understanding the Past".

Historically, the earth's climate has been changing since the earliest of the five major ice ages (more than 2 billion years ago) to the current greenhouse age. The earth has gone from having a methane atmosphere (greenhouse gas) to having excessive oxygen in the atmosphere, presumably from bacterial respiration. The influence of the species and earth causes its climate to change. Just what is climate? Climate is commonly thought of as the expected weather conditions at a given location over time (from Ice-age). People know when they go to New York City in winter, they should take a coat. When they visit the Pacific Northwest, they take an umbrella. Climate can be measured at many geographic and temporal scales—for example, cities, countries, or the entire globe—by such statistics as average temperatures, the average number of rainy days, and the frequency of droughts. *Climate change refers to changes in these statistics over the years, decades, and centuries*.

Climate engineering can be defined as the deliberate large-scale modification of the earth's climate systems to counteract and mitigate anthropogenic climate change. The strategies which fall under this definition are loosely organized into four types: Decarbonizing the Energy Systems, Carbon Dioxide and other Green House Gas (GHG) Removal, Solar Radiation Management (Albedo Modification), and Adaptation to Climate Change. This course is designed to help students understand the historical and engineering perspective of climate change, strategies to engineer earth's climate, monitor and predict climate change, and policies to mitigate risks associated with climate change. Through this course, the students will develop an understanding of the various aspects of science, engineering, economics, and policies of climate change. This course will answer the following questions:

1. How can climate engineering impact global warming and climate change?
2. What is the science behind carbon dioxide removal and albedo modification?
3. What (and how) renewable technologies contribute to decarbonization?
4. How much time will the climate engineering strategies take to impact climate change on the earth?
5. How science, policies, and discussions can inform choices to reduce the risks posed by climate change?

Recommended Texts

1) John Houghton, Global Warming: The Complete Briefing, 5th Edition, 2015, Cambridge Univ. Press.
2) D. Jacob, Introduction to Atmospheric Chemistry
http://acmg.seas.harvard.edu/people/faculty/djj/book/index.html
3) Edmond A. Mathez, and Jason E. Smerdon, Climate Change: The Science of Global Warming and our Energy Future, 2nd Edition, 2018, Columbia University Press, NY

Course Outline
The course will have the following five units and associated lectures:

Unit 1: The History of Climate Change and Introduction to Climate Engineering
1. History of anthropogenic climate change
2. Atmosphere chemistry and greenhouse gas (GHG) emissions
3. Carbon cycle and acidification of oceans
4. Introduction to climate engineering and strategies

Unit 2: Climate Monitoring and Prediction
5. Monitoring climate change using satellites
6. Monitoring of CO_2 and GHG levels in the atmosphere
7. Prediction of climate change – types of climate models
8. Prediction of global warming – Sawyer model, Broecker model, Hansen Model
9. Prediction of global warming – IPCC's models.

Unit 3: Solar Radiation Management (SRM)
10. Earth's thermostat and radiation balance
11. Greenhouse chemistry and the greenhouse effect
12. Radiative forcing and feedback of the climate system
13. SRM strategies – space reflectors and stratospheric aerosols
14. SRM strategies – cloud whitening, albedo modification
15. SRM strategies - other geoengineering techniques

Unit 4: Decarbonization of Energy Systems and GHG Removal
16. Decarbonization - Effective utilization of coal and natural gas
17. Decarbonization – Implementation of nuclear power
18. Decarbonization – Utilizing wind and solar power
19. Decarbonization – Harnessing hydropower
20. Decarbonization – Electrifying transportation with batteries and fuel cells
21. Introduction to carbon dioxide and other GHG removal
22. Carbon capture techniques – Post-combustion, oxyfuel, and pre-combustion
23. Carbon capture from air and seawater
24. Carbon sequestration – mineralization and deep sea injection
25. Carbon recycling – Renewable and green chemicals

Unit 5: Adapting to Climate Change, its Economics, and Policies
26. Adapting to changing ecosystem – deforestation, agriculture and food
27. International climate policy and emissions trading
28. Implementation of climate policy – Kyoto Protocol, international carbon action partnership
29. Economics of climate change – carbon tax, regulating emissions
30. Preparing for the future

Teaching and Learning Methods
A variety of teaching and learning approaches will be used in this course. Each unit will be introduced with a case study. Classes will vary to suit the topic under study and will include a mix of

lectures, demonstrations and group based workshops. All classes will be organized to maximize interaction between the instructor and the students. The emphasis will be on developing a strong understanding of scientific basics and tools for analysis, rather than a descriptive presentation of processes.

Assessment

Assessment Item	**Date**	**Weighting**
Unit Evaluation	Continuous	15%
Exam on Unit 1-2	September	20%
Exam on Unit 3-4	October	20%
Team project	Start: October Submit: December	30%
Final Exam	Exam week	20%

Unit Evaluation: A set of tutorial problems will accompany each unit. These are to be done as homework. Class problem solving sessions are timetabled to help students with these tasks. Students may hand in problem solutions for feedback. Worked solutions will be provided.

Exams: The exams will be open book. Questions will predominantly test students' understanding of the topics covered in classroom. The first two exams will be on Unit 1-2 and Unit 3-4 respectively. The final two-hour exam will assess the whole course, but will be weighted heavily towards unit 5.

Team Project: Students will work in teams of three or four students on a realistic and open ended problem on some aspect of climate change. The project will involve literature survey, planning, data analysis/calculations, an oral presentation and written report. Full details of assessment criteria and timetable will be handed out with the project description.

Grades: The overall points for the course will be the weighted average of the points for each assessment item. The minimum overall points to achieve each grade is
A > 85
B > 75
C > 65
D > 55
F < 45